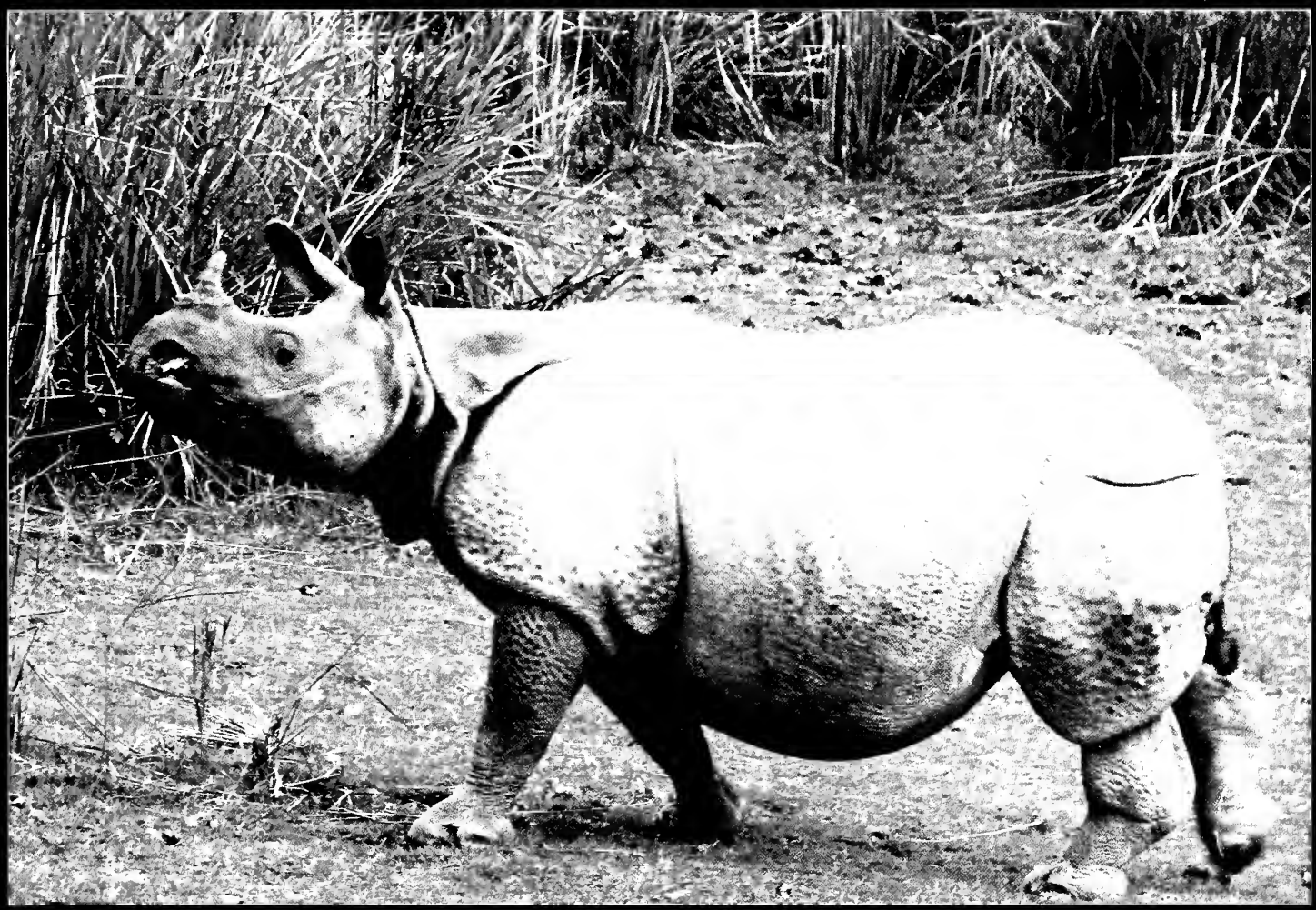
JOURNAL
OF THE
BOMBAY NATURAL HISTORY SOCIETY

APRIL 2008 VOL. 105 (1)



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JOURNAL OF THE BOMBAY NATURAL HISTORY SOCIETY

Hornbill House, Shaheed Bhagat Singh Marg, Mumbai 400 001.

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By Asad R. Rahmani

Editorial

Need for a 'Think Tank' for wildlife conservation in India

Indian wildlife is passing through an extremely critical period where almost all the protected areas and species are under human-related pressures in some way or the other. Common species such as House Sparrow, Black Drongo, Indian Roller are becoming uncommon, the countryside which used to harbour Indian Fox, Jackal, Blackbuck, Black-naped Hare in large numbers is now becoming unfavourable to them. Most protected areas are threatened by all of the following or some of them: roads, railways, dams, urban expansion, over-grazing, invasive species, encroachment, illicit wood cutting, unrestricted tourism and mismanagement or plain neglect. Political exigencies have reduced the Chief Wildlife Warden to a mere rubber stamp who allows activities detrimental to wildlife and wild areas because he has to keep his job.

The fight between wildlife guardians and human right defenders is not going anywhere although both appear to agree for protection of forest and wildlife for human welfare. On top of all this are the looming threats of climate change and human population increase – according to demographic estimates India's population will grow to 1.4-1.5 billion in another 40-45 years before stabilizing. The world population is estimated to grow from the present 6 billion to 10-12 billion. If one adds the increase in the consumption level (the Indian middle class will be 600 to 800 million) in another 40 years, the future of wildlife looks very bleak.

However, there is also a silver lining. There is tremendous awakening and appreciation of wildlife and wild places in the general public and corporates. There are hundreds of examples of community-based and community-led environmental protection. India has strong wildlife laws, and protection of wildlife is in the Concurrent List of the Indian Constitution. The Government of India and many state governments proudly advertise about India's wildlife and protected areas, wildlife tourism is increasing, conservation NGO lobby is strong, the Indian Army guards wildlife under its jurisdiction, and India has signed all important international treaties concerning wildlife and wild areas, and we have not lost any (known) species since Independence.

All this is very good, but predictions appear gloomy. Due to pressure on land (going to increase manifold in future), the innocent days of wildlife protection are over where a Sálim Ali has to write to a Prime Minister and a sanctuary is declared or a species brought under protection, or an Indira Gandhi has to lift the phone and advice a chief minister to protect an area and her diktat is complied. It is now more complicated and difficult. The political equation has changed. A government dependent on the support of various political parties, a prime minister or chief minister has to keep in mind the political fallout of stopping mining or shifting a village from the core area of a critical wildlife habitat. The centre and states are not necessary ruled by the same parties so any advice of the Centre, no matter how useful it may be, is judged politically and not on its merit.

Bickering between wildlife lobby and tribal lobby has reached its zenith, thanks to the controversial Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. The 'wildlife lobby' says that the Act will destroy the remaining forests, while the tribal lobby says that it will reverse the historical wrong done by the British and perpetuated by the Government of India even after Independence on the original forest dwellers. Interestingly, both the lobbies agree that forests need protection from the bigger threats of mining, dams, roads and land sharks that are waiting to pillage the forest. Can we have some common ground when our aims are same – protection of nature? With proper dialogue and mutual understanding with tribal and forest dwellers, we can even use the Forest (Rights) Act to fight destructive mining and dam projects.

Some wildlife enthusiasts say that people and wildlife, particularly large carnivores, cannot live together so villagers should be shifted from certain identified wildlife areas, while the community-oriented organisations say that people have been living with wildlife for thousands of years, and there are numerous examples of this co-existence, so why shift villagers. The government says that remote villages need electricity, roads, medical facilities, clean water and protection from crop depredation by wildlife, while the wildlife lobby demands shifting of these villages outside the forests to provide them all the facilities of modern life. Wildlife lovers are blamed for their indifference to poor tribals and forest dwellers and their (wildlifers) over-reliance to the creaky enforcement

machinery of the foresters and the police. If tribal activists romanticise forest communities, the wildlifers sometimes seem totally uninterested in the welfare of the forest dwellers, except perhaps to click some questionable pictures of tribals.The community-based organisations romanticise the sustainable lifestyle of tribal as a 'Noble Savage', while the wildlife lobby says that such romantic days are over! Look at the reality. It was okay when forests were vast and human population was small and people's aspirations were low. Now which tribal does not deserve or need electricity, modern medical facilities and education for his/her children like everyone else? So, provide them outside the forests, advice the wildlife supporters. But we can also have a middle path. We can find ways of integrating forest conservation with appropriate development facilities through a mix of zoning, alternative livelihood *in situ*, and where necessary relocation of villagers.

The Wildlife (Protection) Act (WPA) was mainly based for the protection of sanctuaries and national parks, and large vertebrates living therein. It is inadequate to protect seascapes, wetlands, and species living in large landscapes. Most of the large sanctuaries, having multiple-use areas established under the WPA, have failed as they do not consider the rights, knowledge, practices, aspiration and increasing/changing demands of people living inside them. Is it right to stop improvement of a road going to a remote village under the *Pradhan Mantri Sadak Yojana* inside 3,162 sq. km Desert National Park? Is it right to stop sale of private land in the Sardarpur Florican Sanctuary? Or, should we stop construction of a new border road in the Changthang Wildlife Sanctuary as the area falls inside a sanctuary? Did we consult the local people, and in case of Changthang, the army, before declaring such sanctuaries? Can we develop a new legislation to take care of the protection of large natural and semi-natural landscapes with multiple users?

There is a dire need for landscape and seascape level approaches of conservation, which combine all forms of conservation from the standpoint of the management functions or objectives – those that provide strict protection to those that allow multiple uses of the land. From the standpoint of the governance, within the land/ sea scapes, we need areas managed by the government agencies and those managed by communities, and the whole range between them. This will become more important as climate change makes ecosystems and species move – they need to have spaces to move into and corridors in between. I think the present PA system in India is inadequate to face such challenges.

With depletion of marine fish stocks (and increasing fish demands), there is a need to develop large Marine Protected Areas (MPAs) where fish and other marine life forms are allowed to breed and recover. Do we have the necessary laws to establish MPAs and wherewithal to monitor them? The IUCN hosted its first International Marine Protected Areas Conference in Australia in 2005, followed by Marine Summit in 2007. The IUCN has called for setting up a global network of MPAs by 2012. Experts say that in order to protect marine biodiversity and allow sustainable fisheries, 20-30 per cent of the seas must be under protection. However, presently only 1 per cent is under protection. Many of these MPAs have to be trans-boundary. Do we have necessary laws and capacity to establish MPAs in the Indian territorial waters? Due to multiplicity of users and stake holders, and large sizes, MPAs need a different approach of protection. They cannot be governed by the WPA, and certainly not managed by the Forest Department. Some could be 'no-take' MPAs (where no extractive uses are permitted) and others could be 'traditional-use' MPAs. Unlike terrestrial PAs, MPAs need not be site specific all the time they can be shifted spatially and temporally. Do we have laws and databases to develop such large MPAs, which can be shifted every five years as the species recover?

It is rightly said that a good war strategist prepares his army keeping the worst-case scenario in mind and has many alternative plans. Unfortunately, we do not have a long-term conservation strategy and our wild-lifers still feel that making a few more sanctuaries (more specifically Critical Wildlife Areas), stopping a road or mine, forcing the government to make WPA more stringent, will save wildlife. Most of our PAs do not even have a vision, conservation targets and long-term plan. Things which have not worked for 60 years will not work in future also, but for many species, we do not have the luxury of time. We have to think 'out-of-the-box' to save them. Can we have a new paradigm shift in our protection and management approach? Should we commercialise wildlife protection, like it is done in South Africa, Tanzania, Kenya, Botswana with great success. Should we allow private parks and sanctuaries in India? Should many more community conservation areas be encouraged? Should we import tourism-based African model of conservation or should it be 'Indianised' to keep our cultural and social sensitivities.

Some of our PAs are suffering from their own success. For example, in Ranthambore and Bandhavgarh there is now a restriction on the number of vehicles entering each day in the park. Nature-based tourism traffic will increase as Indians become rich. Can we replicate the success of Ranthambore in other forests, which are at present neglected? Unfortunately, local people who have to make way for luxury tourist resorts hardly benefit from tourism. Can we provide resources and training to locals to provide home-stays? Home-stay concept is a great success in Ladakh and other remote hill areas. Can this more socially responsible tourism model be replicated in other areas. When we have many good examples of community conservation, why not involve grass-root communities in protection and co-management?

In the absence of proper land use plan of the whole country, we suffer from increasing conflicts for location of factories, dams, ports, Special Economic Zones, mines, oil explorations etc. in or near PAs and other natural areas. We do not even have a national grazing policy as a result of which a bank will loan to a villager to purchase livestock in an area which is already suffering from over-grazing, or an irrigation canal is built in the main grassland of shepherds, displacing and marginalizing them.

As far as I know, no one has done predictive modelling on our PAs and wildlife keeping in mind climate change and resulting demographic shifts of human populations (including from Bangladesh), general increase in human population and consumerism, changing consumer demands both nationally and globally, world trade, social unrests, terrorism and its linkage with smuggling of wildlife product, globalization, increasing consumption of wildlife products by our giant neighbour, and biofuel demands. Can we have various models predicting scenarios at different time intervals to indicate what the future of our wildlife will look like in 2015, 2020, 2025, and so on.

Looking at the increasing complexities of wildlife protection, I suggest that we should establish a Wildlife Think Tank in India consisting of wildlife field scientists, activists, PA managers, foresters, grass-root community leaders, social scientists, corporates, planners, thinkers, armed forces, lawyers, judges, strategists, intellectuals, grass-root social workers, economists, climatologists and visionaries who can talk to each other and come up with issue-based guidelines and strategies. Such think tanks or policy research institutes exist in other fields such as defence, economics and foreign policy, so why not for wildlife?

The days are over when only the mandarins of Ministry of Environment and Forests are expected to show concern about wildlife. Wildlife concerns and interest have to be integrated and internalised by all the departments of the governments. We need visionaries who can tell us what will be the situation of wildlife in India when it becomes as developed as Europe in another 40-50 years. Outdated ways of thinking and repeating failed models of wildlife conservation in 'developed' India will only spell further disaster for our wildlife and wild places.

Asad R. Rahmani

(I would like to thank the following persons for commenting on the draft: Prof. Mahesh Rangarajan, Delhi University; Mr. Ashish Kothari, Kalpavriksh; Dr. Koustubh Sharma, Snow Leopard Trust; Mr. Anand Chandrasekhar, Advocacy Officer, IBA Programme; Dr. Irfan-Ullah, Ashoka Trust for Research in Ecology and the Environment (ATREE))

ACKNOWLEDGEMENT

WE ARE GRATEFUL TO THE MINISTRY OF SCIENCE AND TECHNOLOGY,
GOVT OF INDIA,
FOR ENHANCED FINANCIAL SUPPORT FOR THE PUBLICATION OF THE JOURNAL.

DEMOGRAPHIC STRUCTURE, ACTIVITY PATTERNS, HABITAT USE AND FOOD HABITS OF *RHINOCEROS UNICORNIS* IN CHITWAN NATIONAL PARK, NEPAL

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We studied the time activity budgets, habitat preference, food habits and population structure of the Greater One-horned Rhinoceros *Rhinoceros unicornis* in Chitwan National Park, Nepal by monitoring eight different free ranging rhinos from elephant back for 94.5 hrs (7-24 hours per rhino) and by an intensive survey of rhino habitats from elephant back and a four-wheel drive vehicle in early 2003. We classified 92 rhino sightings into seven age and gender groups. There was a calf for every 2.54 adult female rhino. We found that the adult sex ratio was equal, the proportion of adult rhinos had increased and the calf:cow ratio had decreased compared with earlier studies. We found that rhinos spent most of their time resting (42.9% ±7 SE) and foraging (32.7% ±6.1 SE). There was a foraging peak in the morning and afternoon, and rhinos rested or wallowed during the noon hours. Rhinos were observed to use grasslands, riverine mixed forests and ecotones (grasslands interspersed with mixed forests) and were not observed to use Sal forests and agricultural fields. They preferred to forage in grasslands (50.7% ± 9.9 SE) and ecotones (18.5% ±7.7 SE), preferring riverine mixed forests for resting (73.2% ±16 SE). Food habits of rhinos were estimated from 11,101 bite counts from seven rhinos (155 to 2,785 bites from each rhino) from different habitats. Bite counts were corrected for proportional use of a habitat for foraging and for dry weight per bite, to compute the dry biomass contribution of a food plant to the rhino's diet. Rhinos were observed to feed on 42 different plant species. However, only seven species contributed 85% of the dry biomass consumed by rhinos: these were *Saccharum spontaneum* (33%), *Phragmites karka* (16.7%), *Imperata cylindrica* (16.2%), *Saccharum bengalense* (6%), *Callicarpa macrophylla* (5.1%), *Neranga porphyrocoma* (5%) and *Hemarthrea compressa* (4.8%).

Key words: Indian Rhinoceros, diet composition, population structure, ranging patterns

INTRODUCTION

The Greater One-horned Rhinoceros *Rhinoceros unicornis* henceforth rhinos, once ranged throughout the Gangetic Floodplain (Gee 1959, 1963), but at present, its range has been drastically reduced (Stracey 1957; Rookmaaker 1984; Dinerstein 2003). In recent times, the Greater One-horned Rhinoceros has received much scientific and conservation attention with successful introductions and reintroductions (Laurie 1978, 1982; Jnawali 1995; Dinerstein 2003; Sinha *et al.* 2005). The two largest populations of rhinos are located in Kaziranga National Park (>1,500 rhinos, Vasu 2003) and in Chitwan National Park (>500 rhinos, DNPWC 2000). These two populations hold promise for the long-term viability of the rhino and as a potential source for reintroductions of rhino to parts of their historic range (Dinerstein and McCracken 1990; Sinha and Sawarkar 1993; Dinerstein 2003). Due to ever increasing threats to the habitats in these areas from anthropogenic pressures it is imperative that some form of scientific monitoring be implemented for the species. Herein, we present the findings of a short intensive study on habitat use, activity patterns, food habits and the population structure of the Greater One-horned Rhinoceros in Chitwan National Park, Nepal.

STUDY AREA

The present study was carried out in the Chitwan National Park of Nepal between November 2002 and May 2003. The park is located in the *terai* region bordering India, in the southern portion of the Chitwan Valley between 27° 19′ N 83°55′ E and 27°33′ N 84°58′ E (Fig. 1). The Park covers a pristine area of the Siwalik Hills and river valleys that harbours an unique ecosystem of world significance and is designated as a World Heritage Site. The hillsides (762 m above sea level) are forested with deciduous and semi-deciduous trees, mainly Sal *Shorea robusta*, and the low-lying areas (altitude varies from 107 m to 183 m above sea level) along the rivers in the Park are a mosaic of riverine forest types and grasslands (Laurie 1982). There are substantial areas of floodplain habitat with grassy meadows where grassland communities flourish (Lehmkuhl 1993).

The maximum and minimum temperatures are 38 °C in May and 11 °C in January respectively. The climate is monsoonal, and the average yearly rainfall is more than 2,330 mm; nearly 2,000 mm of precipitation occurs during the monsoon between June and September. Though the study site is north of the tropics, its climate is tropical to

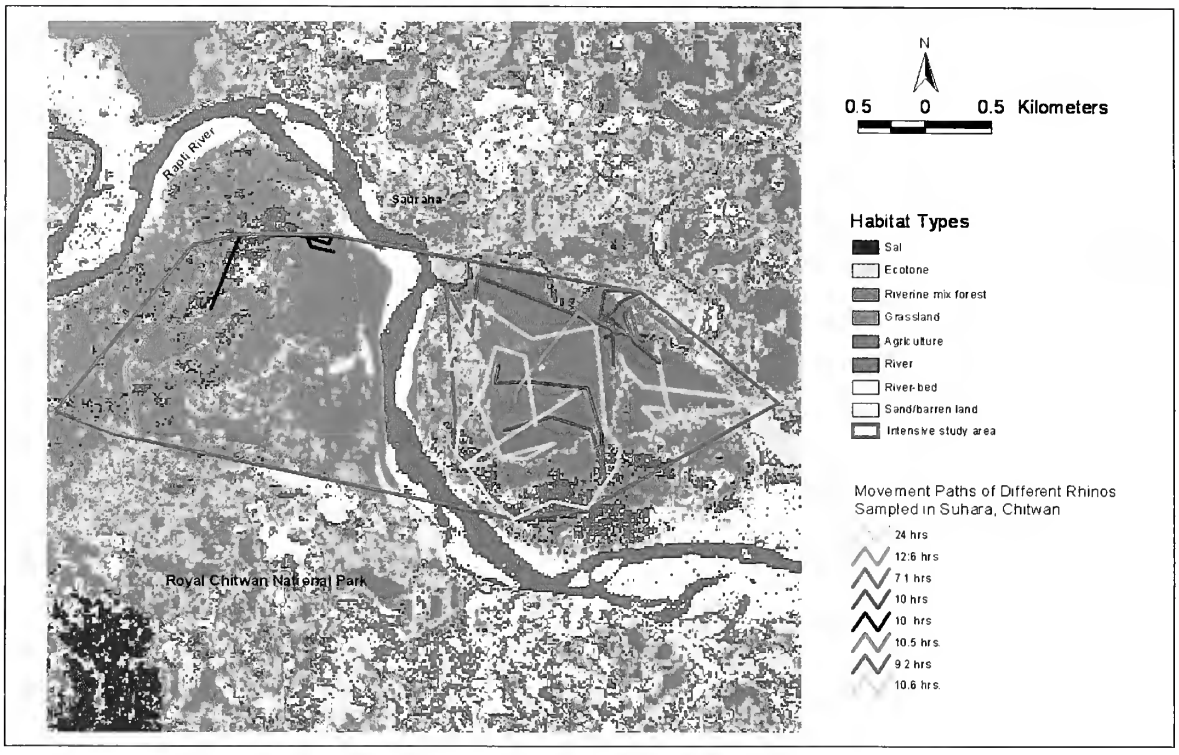

Fig. 1: Habitat types of Sauraha in Chitwan National Park, the minimum convex polygon defining the intensive study area with movement paths of sampled rhinos is shown

subtropical due to the protection of the Great Himalayan Massif running east to west. There are three distinct seasons: winter, spring and summer. The soils in the valley are deep and rich. Surface water is well distributed and available year round.

The Park supports the largest populations of Rhino and Tiger *Panthera tigris* in Nepal. Some other large animals found are Leopard *Panthera pardus*, Gharial *Gavialis gangeticus*, Marsh Crocodile *Crocodylus palustris* and ungulates such as Gaur *Bos gaurus*, Sambar *Cervus unicolor*, Spotted Deer *Axis axis*, Hog Deer *Axis porcinus*, Barking Deer *Muntiacus muntjak* and Wild Pig *Sus scrofa*. Livestock are sympatric with rhinos along the fringes of the National Park and in the buffer zone community forests.

METHODOLOGY

Habitat use, activity, and foraging by rhinos was studied in the Sauraha area comprising the floodplain of the Rapti river with grasslands, riverine forests, mixed forests and ecotonal forests, since this area was easily accessible and had a good rhino density. It was also the study site for earlier studies on rhinos by Laurie (1978), Jnawali (1995) and Dinerstein (2003), thus enabling us to compare our data with those studies. Data from rhino habitats throughout Chitwan were obtained for estimating the demographic structure of the rhino population.

Population Structure of Rhinoceros

Since rhinos are primarily restricted in their distribution to riverine mixed forest, floodplain grasslands and low elevation forests, and rarely venture far from water (Dinerstein 2003), we intensively surveyed such habitats using a four wheel drive vehicle and on elephant back to obtain rhino sightings. Areas were systematically searched once so as to minimise repeated counts of the same individual rhinos. All rhino sightings (n=92) were classified into age and gender groups. Most adults and many immature animals could be distinguished individually using variations in horn size and shape, skin folds and tubercles, scars, ear nicks and tail cuts (Laurie 1982; Dinerstein 2003). These characteristics along with the geographical location of the animals permitted us to identify and exclude rhinos that were encountered more than once during our survey. In order to avoid the biases on exact aging, animals were divided into seven age categories (Laurie 1982; Dinerstein 1991, 2003). These were young calf (<6 months), old calf (>6 months-2 years), juvenile (2-3 years), subadult (3-5 years), young adult (5-10 years), prime adult (10-15 years) and old adult (>15 years) based on body size, condition of skin folds, and shape and size of the horn. Calves that were shorter than their mother's belly line were classified as young calves; they were observed to have smooth skin and were totally dependent on their mother's milk. Older calves, though dependent on suckling also attempt to sample vegetation and were slightly taller than their mother's belly

·line. The height of juvenile rhinos matched that of their mother's chest. Though still associated with their mothers, they tended to venture and often foraged some distance away. Subadult rhinos were almost adult size; they formed a loose association with their mothers and were often seen by themselves or in small groups of similar age and sex. Subadult rhinos had facial characteristics between those of adult and juvenile rhinos. Their skins folds are not fully formed like those of the adults. Rhinos in the adult categories were differentiated based on their height, horn and body size, skin folds and tubercles, and physical and social maturity. Age categories for adult rhinos were developed with the assistance of local field experts who could recognise animals individually and had known them for several years. Age categories were tested for consistency and replicability between local field experts and the authors on several known rhinos prior to field sampling. Average and typical group sizes were calculated (Jarman 1974).

Behavioural observations and ranging patterns

We located rhinos in the early morning hours in the intensive study area and continuously followed the focal animal on elephant back. Rhinos were followed until light conditions prevented observation; night monitoring was done on one night. Eight free ranging rhinos were continuously monitored for 7 to 24 hours each. Data were recorded as duration for all behaviour states and as frequency for events using all occurrence sampling and focal animal sampling (Altmann 1974; Lehner 1996).

Behavioural states were defined in broad categories as (a) foraging, (b) resting, (c) wallowing, (d) walking, (e) running, and (f) standing. A behavioural state was recorded if it lasted more than one minute. Position coordinates obtained using a hand held GPS unit were recorded for all behavioural states and when a rhino moved over 30 m. The habitat types within 10 m and 50 m radii of the rhino were recorded for each behavioural state.

Food Habits

A record was kept on the duration of feeding bouts in different habitats. The total number of bites of each plant species by focal rhinos in different habitats was recorded (Wallmo and Neff 1970; Field 1972; Hobbs *et al.* 1981; Butts *et al.* 1982; Jhala 1997). This was possible in most cases since rhinos permitted a close approach (5-10 m) on elephant back. Most items eaten could be identified from this distance. In cases where identification of forage species was in doubt, direct observation was followed by on-site inspection and collection of samples that were later identified using published checklists (Thapa 1994) and by local plant taxonomists.

Bite Weight and Proportional Consumption of Forage by Rhino

Twenty simulated rhino bites of all major food plants were hand plucked. The fresh weight and dry weight of these simulated bites were determined by oven drying at 60 °C to constant weight (Neff 1967; Wallmo *et al.* 1973). The total number of bites recorded for each food item in each habitat was multiplied by the proportional grazing activity of wild rhinos in that habitat (Jhala 1997). This provided the proportional contribution of different food item bites to the rhino's diet from each habitat type. The dry biomass contribution of different food items to the rhino's diet was computed following Hobbs *et al.* (1981) and Jhala (1997).

Habitat Availability, Use and Ranging Pattern

Satellite imagery (LANDSAT) of Sauraha for February 2002 was classified into eight relevant habitat types using unsupervised and supervised classification (Schowengerdt 1997). These were (1) riverine mixed forest, (2) grassland, (3) ecotone (between grassland and riverine mixed forest), (4) sal forest, (5) agriculture, (6) river/water body, (7) riverbed and (8) sand/barren land using ERDAS IMAGINE (Pouncey *et al.* 1999). The classified image was then imported to Arcview (Arc view 3.1 GIS 1996) for further analysis (Fig. 1).

Movements of each rhino were plotted on the classified image, and the rate of movement was calculated. The extreme rhino locations were connected to define the intensive study area using the 100% minimum convex polygon (MCP) method (Mohr 1947) using the "Animal movement" extension in Arcview. The polygon defining the intensive study area was plotted on the classified imagery using Arcview and the proportions of available habitats within the MCP were obtained. The proportion of time spent in various activities in different habitats was considered as the use of that habitat for a particular activity (Johnson 1980). The analysis for habitat use and availability was carried out using Compositional Analysis (Aebischer *et al.* 1993) to determine habitat preference.

RESULTS

Age and Sex Composition of the Rhino Population in Chitwan

In 92 rhino sightings, 14% of the population was calves and juveniles; more than 70% was adult rhinos (Fig. 2). The adult sex ratio was equal, yielding an estimated calf for every 2.54 adult females. Most rhinos were observed to be solitary. Groups consisted of females with young calves, mating pairs, and male groups of subadult rhinos (Fig. 3). Groups ranged from one to a maximum of seven Rhinos. The average group size was 1.33 and the typical group size was 2.35.

Time Activity Budget and Temporal Variation in Activity Patterns

Over 90 hours observations were recorded from eight free ranging rhinos. Rhinos spent most time resting (43% ±7 SE) followed by foraging (33% ±6.1 SE) (Table 1). The frequency of urination was 0.46 per hour (±0.25 SE); this was because one of the sampled rhinos was a dominant male that was actively scent marking (Fig. 4). Rhinos were seen feeding mostly between 1600 and 1900 hrs (59% ±14.6 SE) followed by 1300 and 1600 hrs (44.9% ±11.6 SE). Only one adult female rhino with a calf was monitored through the night in addition to a full day session (24 hours): this rhino showed a foraging peak (60.14%) followed by resting (23.59%) during the night time. Rhinos were seen wallowing during the hotter hours (1300 to 1600 hrs with 18.70% ± 10.02 SE) (Table 1).

Habitat-wise Activities and Preferences

The habitats used by rhinos were grassland, riverine mixed forest and ecotone (riverine mixed forest interspersed with grassland). The area enclosed by the 100% MCP joining all extreme rhino locations was 7.45 sq. km. This intensive study area was dominated by grassland habitats (34.76%). Other habitats were riverine mixed forest (33.55%), ecotone (12.88%), river bed (16.64%) and barren land/sand (2.16%).

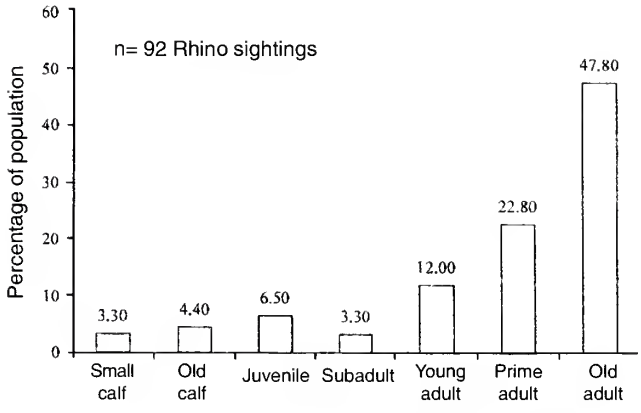

Fig 2: Age structure of the rhinos population in Chitwan, Nepal, 2002-2003

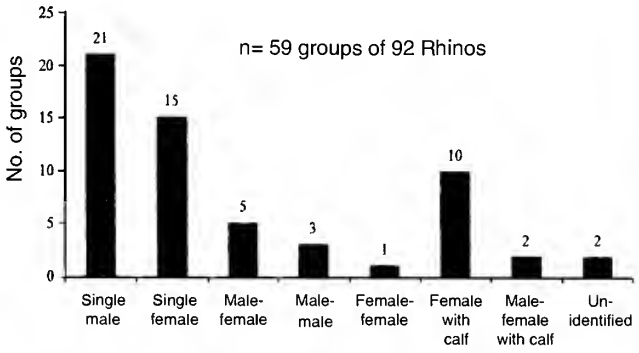

Fig. 3: Group composition of rhinos in Chitwan, Nepal, 2002-2003

Rhinos spent about 30% of the time in the grassland, 57% in riverine mixed forest and 12% in the ecotone. The maximum proportion of time spent feeding was in the grassland (50.76% ±9.9 SE) followed by riverine mixed forest (30.71% ±12.12 SE) and 18.52% (±7.7 SE) in the ecotone (Fig. 5). Rhinos used riverine mixed forests a lot (73.2% ±16 SE) for resting during the afternoon hours (Fig. 5). Standing, moving and wallowing were also more in riverine forests. Compositional Analysis showed that rhinos did not use habitats in proportion to their availability ($F_{(4, 28)} = 3.228$, $p < 0.05$). Compositional analysis for overall habitat use by rhinos (Fig. 6a) ranked the habitats in order of preference as: riverine mixed forest>ecotone>grassland>barren land>river bed. The habitat preference for foraging by rhinos (Fig. 6b) was rated as: grassland>ecotone>riverine mixed forest>barren land>river bed. On the other hand, riverine mix forest was used (66.2%) more than its availability (33.6%) for resting (Fig. 6c). The preference ranking by compositional analysis for resting was: riverine mixed forest>grassland>ecotone>barren land>river bed.

Food Habits

Forty-two species of plants were recorded to be eaten by rhinos during this study (Table 2). The Shannon-Weiner diet diversity was computed to be H'=1.06. Of these 42 species, 16 species contributed more than 1% to the total dry biomass consumption. These 16 species summed up to

Table 1: Proportion of time (mean ± SE) spent in different activities by eight free ranging rhinos during different time intervals of the day

Activities	Total Time	0700-1000 hrs	1000-1300 hrs	1300-1600 hrs	1600-1900 hrs	Night
Resting	0.43±0.07	0.58±0.13	0.36±0.10	0.07±0.03	0.00±0.00	0.23
Standing	0.03±0.01	0.03±0.01	0.06±0.02	0.08±0.03	0.04±0.03	0.06
Feeding	0.33±0.06	0.18±0.07	0.33±0.08	0.52±0.10	0.67±0.13	0.60
Moving	0.08±0.03	0.04±0.01	0.09±0.04	0.06±0.01	0.27±0.12	0.10
Running	0.01±0.01	0	0.01±0.01	0	0	0
Wallowing	0.14±0.06	0.15±0.12	0.12±0.12	0.24±0.11	0.003±0.003	0

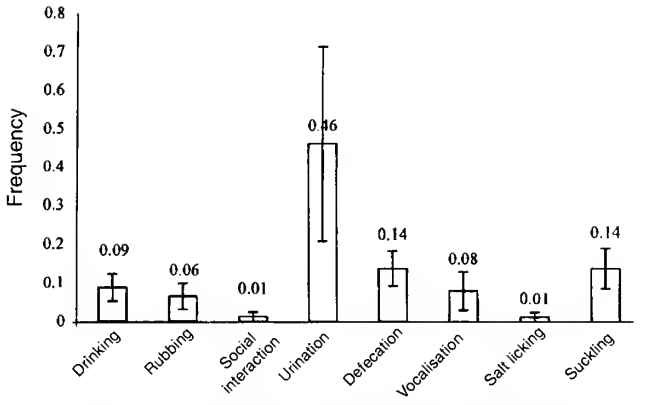

Fig. 4: Frequency of activity events (per hour) of eight free ranging rhinos in Sauraha, Chitwan National Park, Nepal (n= 94.5 hours observation, error bars are SE)

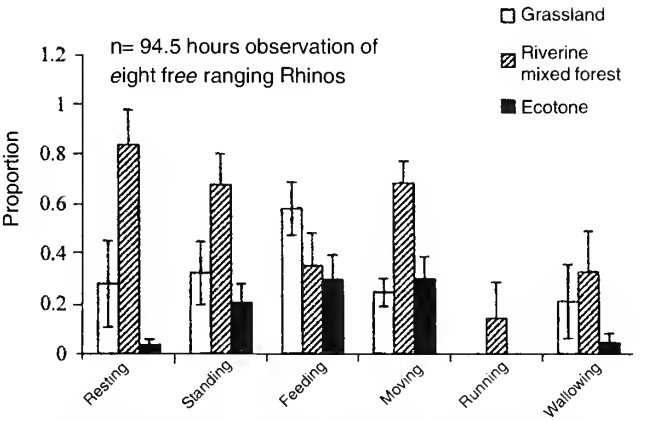

Fig. 5: Proportion of time spent in different activities by wild rhinos in different habitats in the Sauraha area of Chitwan National Park, Nepal

95.3% of the total bite counts. The maximum number of bites was recorded for *Saccharum spontaneum* (34.20%) followed by *Imperata cylindrica* (10.98%), *Dryopteris cochleata* (9.42%) and *Coffea bengalensis* (8.18%).

On converting bite counts to dry biomass consumption based on hand simulated rhino bites and further correcting each food species' contribution by the proportional foraging activity in different habitats, the rhinos' actual diet in the Sauraha area was estimated (Table 3). *Saccharum spontaneum* contributed 32.69% dry biomass to the diet of the Rhino, followed by *Phragmites karka* (16.71%) and *Imperata cylindrica* (16.22%) (Table 3). These three species together contributed more than 65% of the dry biomass to the rhino's diet. Other species such as *Clerodendron viscosum*, *Tetrastigma serrulatum*, and *Equisetum debile*, though avidly eaten, contributed <1% dry matter to its overall diet due to limited availability.

DISCUSSION

Age and Sex Composition

Information on the age and sex composition of the rhino population provides a valuable insight into the

Table 2: List of plant species eaten by rhino in Sauraha, Chitwan National Park, Nepal

S. No.	Species eaten	Habit	S. No.	Species eaten	Habit
1	*Ageratum conyzoides*	Browse	22	*Flemengia strobilifera*	Browse
2	*Albizzia julibrissin*	Browse	23	*Hemarthrea compressa**	Grass
3	*Artemisia dubia*	Browse	24	*Imperata cylindrica**	Grass
4	*Bombax ceiba*	Browse	25	*Lantana camara*	Browse
5	*Caesalpinia decapetala*	Browse	26	*Litsea monopetala**	Browse
6	*Callicarpa macrophylla**	Browse	27	*Michenia chinesis*	Browse
7	*Cannia bichotoma*	Browse	28	*Mucuna nigricans*	Browse
8	*Chrysopogon aciculatus*	Grass	29	*Murraya paniculata*	Browse
9	*Clematis gouriana*	Browse	30	*Narenga porphyrocoma**	Grass
10	*Clerodendron viscosum*	Browse	31	*Phragmites karka**	Grass
11	*Coffea bengalensis**	Browse	32	*Progesterone bengalensis*	Browse
12	*Coix* sp.	Grass	33	*Saccharum bengalense**	Grass
13	*Colebrookea oppositifolia*	Browse	34	*Saccharum munja*	Grass
14	*Cynodon dactylon*	Grass	35	*Saccharum spontaneum**	Grass
15	*Cyperus rotundus*	Sedge	36	*Scoparia dulcis*	Browse
16	*Desmostachya bipinnata**	Grass	37	*Selaginella monospora*	Browse
17	*Disoxylum binnectiforum*	Browse	38	*Spiranthes sinensis*	Browse
18	*Dryopteris cochleata**	Browse	39	*Tetrastigma serrulatum*	Browse
19	*Equisetum debile*	Browse	40	*Themeda arundinacea*	Grass
20	*Eragrostis tenella**	Grass	41	*Typha angustifolia*	Sedge
21	*Eupatorium adenophorum*	Browse	42	*Vallaris solanaceae*	Browse

* Species that contributed >1% (dry matter) to the Rhinoceros' diet.

demographic process and the health of the population (Caughley 1977). The population structure reported by Laurie (1978) in Chitwan was 52% adult, 21% subadult and 26.5% juvenile, and the adult sex ratio was 62 males to 100 females. Seidensticker (1976) reported 38 males to 100 females with 83 young Rhinos, and Dinerstein (1991) reported a calf for every 1.64 adult females, an adult sex ratio of 66 males to 100 females and a population structure of 23% calves, 13% subadult rhinos and 63% adult rhinos in the same place. Spillet (1967) reported 81 males to 100 females in Kaziranga National Park (India). Comparing the population over time (Laurie 1978; DNPWC 2000) suggests that the proportion of adult Rhinos in the population is increasing in relation to the subadults and calves.

The population of Black Rhinos *Diceros bicornis* was reported to have an excess of males with >60% adults, and <20% of sub-adults and juveniles, while the White Rhino *Ceratotherium simum* population was composed of adult males (19%), females (27%), subadults (32%) and calves (22.5%) (Owen-Smith 1988). The adult sex ratio of Black Rhino was similar to the present adult and male/female ratio of the Greater One-horned Rhino in Chitwan. Seidensticker (1976) reported a rhino calf for every 1.2 adult females while Laurie (1982) reported a calf for every 1.31 adult females for the late 1970s in Chitwan. The present study reports 1 calf for every 2.54 adult female rhinos with calves forming 14% of the population. The adult female population was 36%, adult males 35% and subadults 15% of the population. These statistics are comparable to the 1975 population (Laurie 1978), and the 1988 population as reported by Dinerstein (2003). A greater proportion of adult rhinos and a smaller calf-to-cow ratio is suggestive of a decline in the growth rate of the rhino population in Chitwan. This trend is a cause for concern since the Chitwan rhino population serves as a source population for introducing and supplementing rhino populations in other areas of Nepal (DNPWC 2000; Dinerstein 2003).

Table 3: Dry biomass contribution of different plant species to the Rhinos' diet from bite count and habitat use data in Sauraha area of Chitwan National Park, Nepal

S. No.	Food items (species)	Habitats (n = 11,101 bites)			A	B		C
		GL * 7,643 bites	RMF** 1,025 bites	EF*** 2,433 bites	Total percent in diet	Dry wt (g) per bite	Dry wt (g) in 100 bites	Percent dry biomass in diet
1	*Clerodendron viscosum*	0.00	0.99	0.00	0.99	1.81	1.79	0.8
2	*Tetrastigma serrulatum*	0.00	1.17	0.04	1.21	1.51	1.82	0.8
3	*Desmostachya bipinnata*	0.00	1.41	0.01	1.42	2.44	3.45	1.6
4	*Equisetum debile*	0.00	0.00	1.49	1.49	0.14	0.21	0.1
5	*Cynadon dactylon*	2.03	0.00	0.02	2.05	0.95	1.95	0.9
6	*Litsea monopetala*	0.00	2.04	0.03	2.07	3.74	7.73	3.6
7	*Narenga porphyrocoma*	1.61	0.00	0.58	2.19	4.97	10.86	5.0
8	*Eragrostis tenella*	1.67	0.00	0.69	2.36	1.46	3.45	1.6
9	*Hemarthrea compressa*	3.78	0.00	0.00	3.78	2.78	10.51	4.8
10	*Saccharum bengalense*	3.51	0.00	0.40	3.91	3.35	13.08	6.0
11	*Callicarpa macrophylla*	0.01	5.36	0.05	5.42	2.05	11.09	5.1
12	*Phragmites karka*	2.74	0.00	2.98	5.71	6.37	36.36	16.7
13	*Coffea bengalensis*	0.00	8.18	0.00	8.18	0.62	5.07	2.3
14	*Dryopteris cochleata*	0.09	9.32	0.02	9.42	2.49	3.78	1.7
15	*Imperata cylindrica*	10.98	0.00	0.00	10.98	3.22	35.30	16.2
16	*Saccharum spontaneum*	23.80	0.00	10.41	34.21	2.08	71.15	32.7
	Others				4.80			
	Proportion of time spent feeding in each habitat (SE)	0.507 (0.09)	0.307 (0.121)	0.185 (0.077)				

* Percentage of bites of a food item in the grassland multiplied by proportional grazing activity in grassland (GL).

** Percentage of bites of a food item in the riverine mixed forest (RMF) multiplied by proportional grazing activity in the riverine mixed forest.

*** Percentage of bites of a food item in the ecotone forest (EF) habitat multiplied by proportional grazing activity in the ecotone.

A= sum of proportions for each food species from all the three habitats.

B= contribution by dry weight of food items in 100 bites (A* dry weight per bite).

C= percentage contribution in dry weight to the actual diet, (B/∑B)*100.

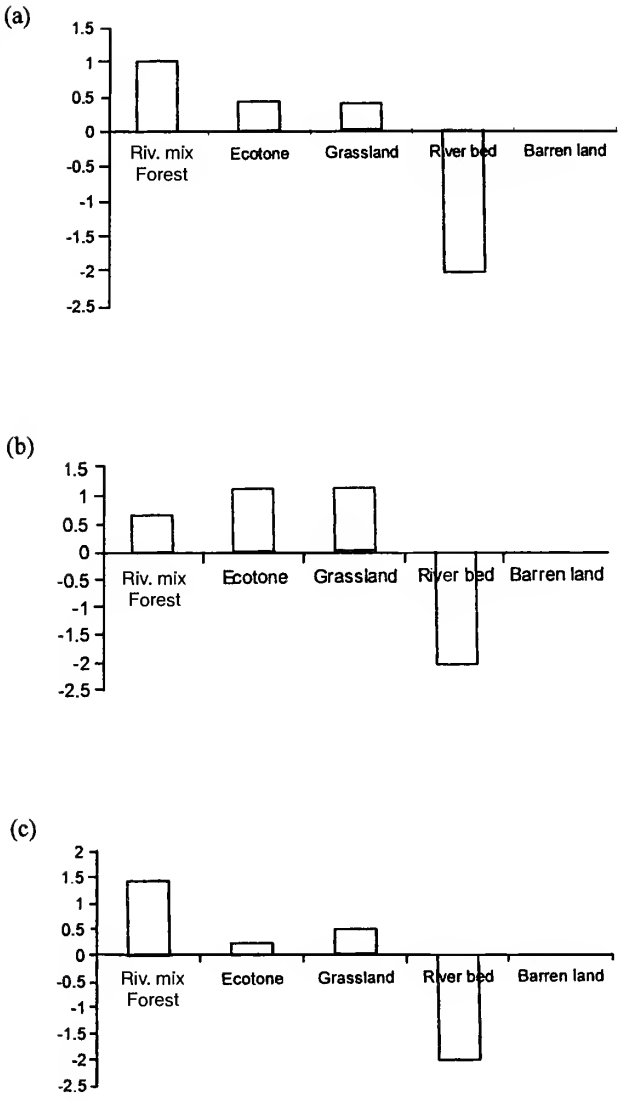

Fig. 6: Results of the difference matrix of Compositional Analysis: (a) overall habitat preference; (b) habitat preference for foraging; (c) habitat preference for resting by Rhinos in the Sauraha area of Chitwan National Park, Nepal

Habitat Use

Rhinos are obligate floodplain habitat specialists (Dinerstein 2003). In this study we defined the intensive study area by joining the outermost rhino locations, thereby restricting further analysis of use and preference within rhino habitats. In the intensive study area, rhinos had access to a variety of habitats including Sal forests and agricultural fields. Rhinos clearly preferred riverine mixed forest and grasslands. However, from the Compositional Analysis results for specific activities, it was evident that rhinos have different habitat preferences for different activities. For foraging they preferred grasslands and ecotones, and for resting there was a clear preference for riverine mixed forests. Thus, by just considering the overall habitat preference of rhinos, one would tend to miss the critical needs of certain habitats for specific activities. It is evident that a landscape that has a mosaic of grassland, ecotone and riverine forests would be ideal for rhinos since these would meet all the various needs of the species.

Diet

The major portion of the rhino's diet was composed of *Saccharum spontaneum, Imperata cylindrica* and *Phragmites karka*; this shows that they largely rely on short grasslands, as also reported by Litvaitis *et al.* (1996), Peet *et al.* (1999), Laurie (1982) and Owen-Smith (1988), for obtaining food. Dinerstein (2003) reports that Rhinos attain their highest densities in *Saccharum spontaneum* grassland habitats. Other species such as *Clerodendron viscosum*, *Tetrastigma serrulatum* and *Equisetum debile* were eaten avidly, but they contributed <1% dry matter to the overall Rhino diet due to their low availability and highly seasonal habit. A greater proportion of time was spent in riverine forest and ecotones where food, shelter and wallowing places are in close proximity. Rhinos were observed to move between habitats for food resources, resting places or water. In Rhino habitats where water is scarce, the management of water sources in a well-dispersed manner is essential.

None of the study rhinos visited agricultural fields or sal forests that were in close proximity. This is likely due to a high risk of contact with humans in agricultural areas and poor forage availability and quality in the sal understorey. Rhino shared the *Saccharum spontaneum* dominated grassland areas with Spotted Deer, Sambar, Hog Deer and domestic livestock (cattle and buffalo). Domestic livestock used grassland habitats during the day. Though none of the sampled rhinos visited agricultural fields, crop raiding by rhinos in fields adjoining the protected area was known to occur. The magnitude of this conflict was not severe, suggesting that most rhinos obtained their nutritional needs from the protected area. Based on discussions with local villagers, rhinos were understood to raid crops at night. Since this study did not employ radio-telemetry, it was difficult to monitor rhinos through the night. Our limited sample of only one female rhino and calf pair that was followed through the night may under represent the use of agricultural fields by rhinos. However, data from an earlier study on radio-collared rhinos in the same study area (Dinerstein 2003) also do not highlight utilisation of crop fields for foraging.

Food Habits

The high proportion of grasses in the diet of rhinos during the hot season in Chitwan was explained by the availability of high quality *Saccharum spontaneum* that keeps

sprouting immediately after grazing and grass cutting (Dinerstein and Price 1991) and burning (Laurie 1978) due to a high substrate moisture (Jnawali 1995). Rhinos ate a wide variety of food items, but the bulk of the diet consisted mainly of relatively few types, as also reported by Laurie (1982) and Dinerstein (2003). Rhinos are considered to be generalist bulk feeders (Owen-Smith 1988). However, Indian Rhinos are relatively selective of more preferable food parts for nutrients and palatability using their prehensile upper lip. Rhinos were observed to selectively feed on the tenderest of shoots of even the coarse grasses.

Laurie (1978) recorded over 100 species of plant eaten by rhino during a year-round study of a larger area from direct observations. Jnawali (1995) reported 28 species based on faecal analysis with a Shanon-Weiner diet diversity of H'= 1.12 in the same area of Sauraha where the current study was conducted. The present study reports a higher diet richness of 42 species of plants eaten with a diet diversity of H'=1.06. Most species reported to be important in the rhino's diet by Jnawali (1995) and Dinerstein (2003) were also observed to be avidly eaten in this study, e.g. *Saccharum spontaneum*, *Imperata cylindrica* and *Phragmites karka*. However, Jnawali (1995) reported a high occurrence of *Narenga porphyrocoma* in faecal analysis, which constituted only 5% of the dry biomass to the rhino's diet in this study. This could likely be due to a change in *N. porphyrocoma*'s availability or due to its coarse nature leading to a high content of undigested residue in the faeces.

Rhinos were observed to feed on 29 different species in the ecotone forests, 20 species in grasslands and 16 species in mixed forests. We did not observe rhinos feeding on the fruit of *Trewia nudiflora* since our study did not include the fruiting season of this species. Jnawali's (1995) report *Trewia nudiflora* fruits constituting 13.4% of the rhino's diet highlights the seasonal importance of certain food items to the rhino's diet (Dinerstein and Wemmer 1988; Dinerstein 2003). Though such seasonally available food items may contribute significantly to the micro-nutrient needs of the rhino (Robbins 1983), the bulk of the annual biomass and energy needs are met from the seven important food plant species, namely *Saccharum spontaneum*, *Imperata cylindrica*, *Phragmites karka*, *Saccharum bengalense*, *Callicarpa macrophylla*, *Narenga porphyrocoma* and *Hemerthrea compressa*, which constituted >85% of the dry biomass consumption by rhinos. This highlights the importance of managing short grasslands for productivity and reducing livestock pressure in these areas.

Management Perspectives

The single most important natural force that maintains the successional mosaic of habitats so critical for rhinos is the periodic floods of the Himalayan region (Burton *et al.* 1989). These floods destroy existing habitats, create new ones and enrich them with fertile sediments. Rhinos further modify their habitats like other mega herbivores, making them favourable for other ungulates (Dinerstein 1980, 2003). Ironically, these very rhino habitat sustaining floods now cause havoc to rhinos. This is because there is only a limited area available for rhinos to live in, the rest having been taken over permanently by humans for agriculture and settlement. When floods destroy existing rhino habitats, there are no "new" habitats formed that are available to rhinos. The Park management now needs to intervene with these natural processes and ensure that critical needs for the rhinos are met, e.g. by creating artificial wallows or by arresting the succession of grasslands to woodlands artificially (by burning and/or cutting woody species) (Dinerstein 2003). Areas likely to be utilised by rhinos for drinking such as streams, rivers, ox-bow lakes, small puddles and wallows need to be regularly maintained.

Though the duration of the study was short, it covers the pinch period for rhinos in Chitwan (late winter and dry season). The study highlights the importance of intermittent intensive studies to find the pulse of tropical systems. The population structure of rhinos with fewer calves per adult female is indicative of a reduction in the rate of increase (Caughley 1977). Based on the food habits and habitat use by rhinos, we highlight the importance of a few food plants like *Saccharum spontaneum*, *Phragmites karka* and *Imperata cylindrica* which constitute more than 65% of the dry matter intake by rhinos. The study highlights the relative importance of short grasslands and riverine mixed forest habitats for effective conservation of rhinos in Chitwan and similar Terai habitats as also reported by Dinerstein (2003).

ACKNOWLEDGEMENTS

The study was funded by WWF Nepal Program, Wildlife Institute of India and the U.S. Fish and Wildlife Service. We are grateful to the Dept. of National Parks & Wildlife Conservation, Nepal, National Nature Conservation Trust, and International Trust for Nature Conservation for facilitating this research. We thank T. Maskey, S. Amatya, U.R. Sharma, N. Poudel, F. Bagley, P.B. Shrestha, N. Dhakal, D. Thapa, S. Bajimaya, G. Upadhyay, Q. Qureshi and V.B. Sawarkar for encouragement and logistic support. B.B. Lama's local field knowledge was indispensable.

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ADVERTISEMENT CALLS OF INDIAN AND SRI LANKAN FROGS[1]

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Acoustic characteristics of the advertisement calls of five Indian and one Sri Lankan frog are described, of which three (*Euphlyctis hexadactylus*, *Sylvirana aurantiaca* and *Ramanella obscura*) are reported for the first time. Temporal and spectral parameters of the calls are given for each species, together with field observations of the environment where the males were located during calling. The results are compared with available acoustic data on the same or related species.

Key words: advertisement calls, frogs, India, Sri Lanka

INTRODUCTION

Call structures are one of the most important attributes of frog species. The most common frog call, the advertisement call, plays an important role in attracting conspecific females and is hence species-specific (e.g. Sullivan *et al.* 1995). Thus, we can identify frog species readily based on call characteristics, even if we cannot observe the calling frog itself. This is a very useful means of surveying anuran fauna in a given locality, and many morphologically similar species have been described based primarily on acoustic differences (Johnson 1959; Kuramoto 1980).

Calls of about 40 Indian frog species have been analyzed (Kanamadi *et al.* 1994, 1995; Roy 1996, 1997; Kadadevaru *et al.* 2000, 2002; Kuramoto and Joshy 2001). Here, we give acoustic analyses of five Indian and one Sri Lankan frog species, of which call structures of *Euphlyctis hexadactylus* (Lesson), *Sylvirana aurantiaca* (Boulenger) and *Ramanella obscura* (Günther) are reported for the first time. Encounter calls of *R. obscura* are also reported.

MATERIAL AND METHODS

Advertisement calls of the six frog species were recorded in the field using a cassette-recorder (TCM-AP5) or MD-recorder (MZ-B10). The calls of *Bufo scaber* Schneider were recorded in Mudigere, Chickmagalur district, Karnataka, on July 9, 2005 at an air temperature of 21 °C; *Euphlyctis cyanophlyctis* (Schneider) in Karnoor, Dakshin Kannada district of Karnataka, on July 10, 2004 at 27 °C; *Euphlyctis hexadactylus* (Lesson) in Adyar, Mangalore, on July 19, 2005 at 25 °C; *Sylvirana aurantiaca* Boulenger in Karnoor (date and temperature were the same as in *E. cyanophlyctis*) and in Aralam, Kannur district, Kerala, on July 14, 2005 at 25 °C; *Ramanella montana* (Jerdon) in Talagini, Shimoga district, Karnataka, on July 23, 2004 at 24 °C; and *Ramanella obscura* (Günther) in Kandy, Central Province, Sri Lanka, on May 30, 2000 at 23 °C. Recorded calls were analyzed using Avisoft SAS Lab Light software. Voucher specimens have been deposited in Rondano Biodiversity Research Laboratory (RBRL), St. Aloysius College, India.

Generally, the calls of many frog species are a series of pulse groups, herein referred to as 'notes'. Some calls are a series of single pulses, also referred to here as 'notes'. Thus, the calls are composed of either multi-pulse or single-pulse notes. Note-interval means the time between the beginning of a note and the beginning of the next note, and the pulse repetition rate is the number of pulses per sec. Measurement values are expressed as the mean ± standard deviation with sample size (n) in parenthesis.

RESULTS AND DISCUSSION

Bufo scaber Schneider

Male calls were heard in paddy fields from individuals floating in shallow water among the rice plants. The toads were whitish in colour at night and dark brown during the day. There were many calling males of *Fejervarya* sp. on the bunds of the paddy fields.

The call was long and consisted of many fast-repeated notes (Fig. 1). The number of pulses in a note was 8.0 ±0.67 (n=19), the note duration was 0.30 ±0.03 sec, and the pulse repetition rate was 23.7 ±0.94 pulses/sec. Notes were repeated at an interval of 0.42 ±0.02 sec. The dominant frequency was about 3 kHz, and there seemed to be a second harmonic band at about 6 kHz.

Kanamadi *et al.* (1995) reported detailed analysis of the advertisement calls of *B. scaber* (as *B. fergusonii* Boulenger). Their calculations of temporal features included initial stages of calls with notes consisting of a few pulses, thus their mean values were slightly lower than those in the present study. The pulse repetition rate was much higher in

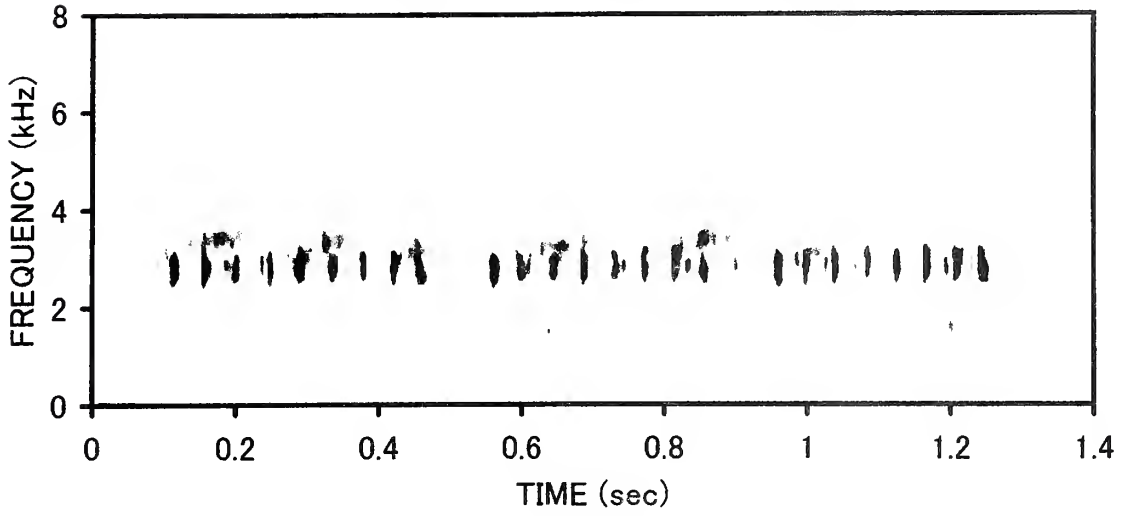

Fig. 1: Three successive notes in the advertisement call of *Bufo scaber* Schneider

Kanamadi *et al.* (1995), possibly, to some extent, due to the higher temperatures during their sound recordings.

Voucher specimen: RBRL05070925.

Euphlyctis cyanophlyctis (Schneider)

Calling males were observed in wetland areas with shallow water, together with those of *Fejervarya* sp. and *Microhyla ornata* (Duméril and Bibron). The calls were loud, metallic and prominent among the choruses of the breeding aggregations of many frog species.

The entire advertisement call was a series of short sharp notes. Typically, a series began with several notes composed of a single pulse, followed by notes composed of double pulses (Fig. 2), although there were variations. Single-pulse notes were repeated more rapidly than double-pulse notes (2.28 ±0.28 vs. 1.52 ±0.15 notes/sec, n=7), and the pulse interval between two pulses in the latter notes was about 0.085 sec. The dominant frequencies were about 3.5 and 1.5 kHz, and the calls showed a weak harmonic structure.

Call structures of *E. cyanophlyctis* were previously described by Roy and Elepfandt (1993), Kanamadi (1996) and Roy (1996, 1997). The general call pattern in the present study resembled that of Kanamadi (1996), who documented calls consisting mainly of double-pulse notes, but differed remarkably in the pulse repetition rate (*c.* 20 pulses/sec in Kanamadi). The calls in Assam and Meghalaya (Roy and Elepfandt 1993; Roy 1996, 1997) differed from those in the present study, primarily due to the greater number of pulses in a note (mean=7). Whether these conspicuous differences indicate geographical or ecological variations should be examined in future studies. Moreover, the presence of a cryptic species cannot be excluded.

Voucher specimen: RBRL04071140.

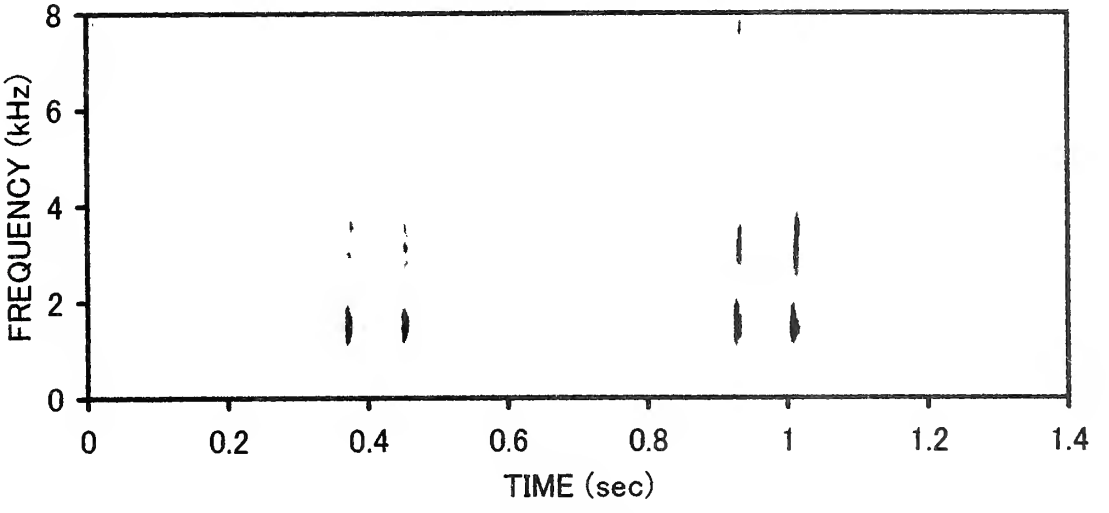

Fig. 2: Two successive double-pulse notes in the advertisement call of *Euphlyctis cyanophlyctis* (Schneider)

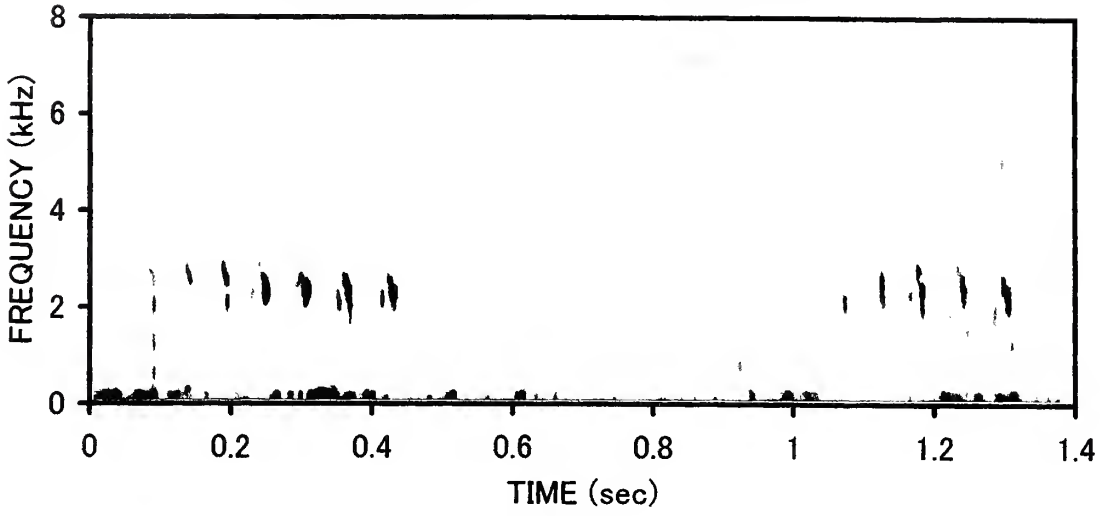

Fig. 3: Two successive notes in the advertisement call of *Euphlyctis hexadactylus* (Lesson)

Euphlyctis hexadactylus (Lesson)

Calling males were observed in relatively shallow water among vegetation in a flooded wetland near a pond previously used to observe this large species. *Sylvirana aurantiaca* Boulenger calls were also heard at this location.

The advertisement call was composed of slowly repeated multi-pulse notes (Fig. 3). The number of pulses in a note was 5.0 ±1.18 (n=24), the note duration was 0.25 ±0.07 sec, and the pulse repetition rate was 16.8 ±0.56 pulses/sec. The notes were repeated at an interval of 1.10 ±0.15 sec. The first pulse in a note was weak, with a relatively low dominant frequency (2.09 ±0.10 kHz, n=8). The dominant frequency tended to decrease from the second (2.43 ±0.09 kHz) to the last pulse (2.29 ±0.11 kHz), and there was a second harmonic band at 5.20 ±0.32 kHz (second pulse) and 4.68 ±0.17 kHz (last pulse).

The call of *E. hexadactylus* differed completely from that of *E. cyanophlyctis*. It was rather high-pitched, which was unexpected considering its large body size. Also unexpectedly, male calls were heard in relatively shallow waters, but not in a pond. Daniel (2002) described that the eggs of this species are thought to be laid in paddy fields. The spawning site of this species should be confirmed in future studies.

Voucher specimens: RBRL05071901, 05071902.

Sylvirana aurantiaca Boulenger

In Karnoor, male calls were heard on the grassy bank of a creek, while in Aralam they were heard among low vegetation, together with those of *Fejervarya* (*Minervarya*) *sahyadris* (Dubois, Ohler and Biju). In Mangalore, calling males were observed near ditches around paddy fields on a hillside, where *Polypedates maculatus* Gray is known to breed. The calls were weak and could not be heard from a distance.

The calls began with a series of single-pulse notes (0.03-0.05 sec in duration) followed by a series of double-pulse notes (Fig. 4). In the calls recorded at Aralam, the note-interval between single-pulse notes was 0.66 ±0.12 sec (n=9) and that between double-pulse notes was 0.57 ±0.12 sec (n=15). The length of a single-pulse note was 0.03-0.05 sec and that of a double-pulse note was about 0.1 sec. The dominant frequency was about 3.7 kHz. An indistinct harmonic structure and weak frequency modulation were recognized.

The advertisement calls of *Sylvirana aurantiaca* resembled those of *Sylvirana temporalis* (Günther) (Kuramoto and Joshy 2001), but the call length was shorter and with a higher dominant frequency in the former. The general similarity in the call structures of these two morphologically similar species supports their close relationship as members of the subgenus *Sylvirana*.

Voucher specimen: RBRL04071136.

Ramanella montana (Jerdon)

Calls were heard from individuals floating on shallow water in paddy fields, among loud choruses of *Fejervarya* sp.; the males were observed calling only from the bank. The call of *Ramanella montana* was easily recognizable due to its unique tune. Like *B. scaber*, the body colour of this species was whitish in the night and dark brown during the day.

The calls were 0.20 ±0.01 sec in duration (n=14) and composed of 5-6 pulses repeated at a rate 23.4 ±2.7 pulses/sec (pulse interval: 0.043 ±0.006 sec; Fig. 5a). The dominant frequency was about 2 kHz, and there was always a seemingly continuous frequency band of about 0.53 kHz. Frequencies higher than 4 kHz were almost lacking.

Within the series of the common call described above, there were a few calls that differed in pulse structure

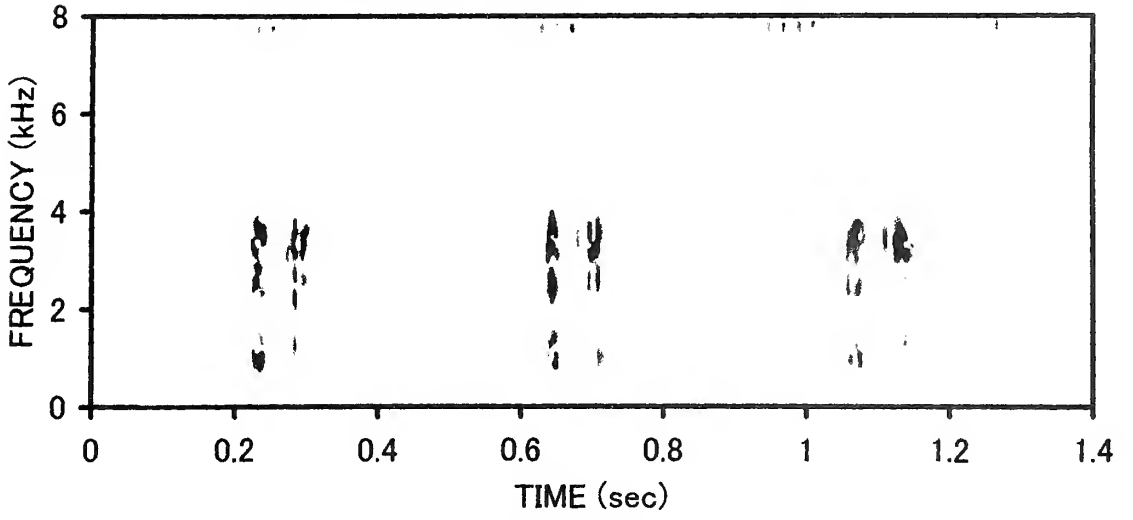

Fig. 4: Three successive double-pulse notes in the advertisement call of *Sylvirana aurantiaca* Boulenger recorded at Aralam

(Fig. 5b). They contained about 10 short pulses with a pulse interval of 0.02 sec and a pulse repetition rate of about 50 pulses/sec; frequency features were similar as in the common calls. The role of this call is unknown at present.

Call structures of *R. montana* were previously reported by Kadadevaru *et al.* (1998). In their sonogram we recognized five or six pulses; they apparently enumerated the number of peaks in a waveform envelope as the pulse number. The dominant frequency band was about 2 kHz in their report and no higher frequencies were reported as in our results. However, a rather distinct first pulse and clear fine harmonic bands in their sonogram were not obvious in our sonograms. Differing from *R. montana, R. variegata* (Stoliczka) seems to have a single-pulsed call of about 0.2 sec duration (Kanamadi *et al.* 1993).

Voucher specimens: RBRL04072302, 04072303.

Ramanella obscura (Günther)

Calls of this species was heard in ditches along a mountain roadside from individuals floating on the water surface. No other frog species was observed in these ditches, whereas many *Philautus* species were heard calling among nearby bushes.

The calls were 0.21 ±0.04 sec in duration (n=12; Fig. 5c), consisting of 7-17 (11.9 ±2.9) indistinct irregular pulses. The pulse interval was 0.02 ±0.003 sec and the pulse repetition rate was 51.7 ±7.5 pulses/sec. The dominant frequency band was about 2.6 kHz with a lower frequency

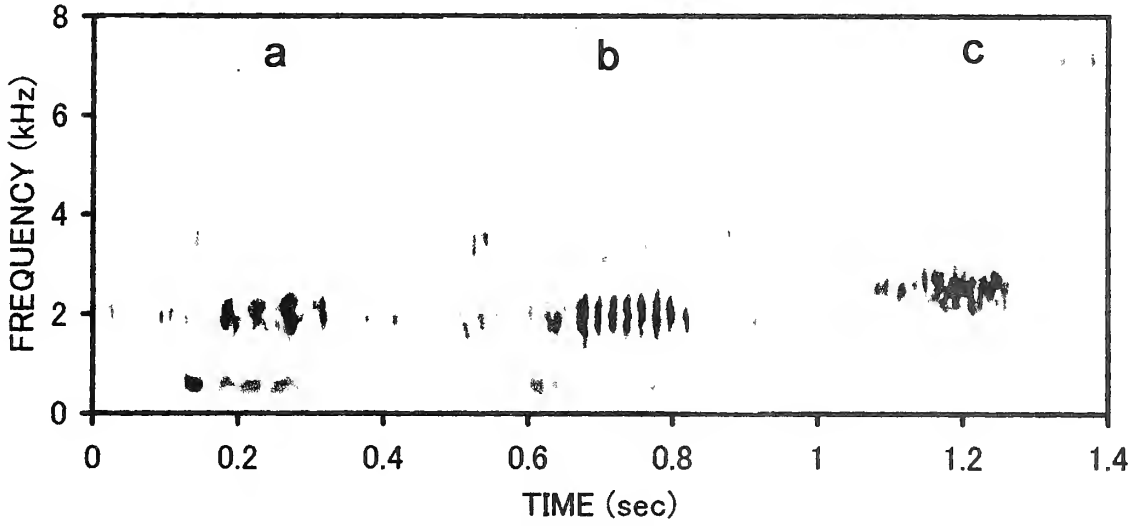

Fig. 5: Notes in the advertisement calls: 5a-b. *Ramanella montana* (Jerdon); 5c. *Ramanella obscura* (Günther)

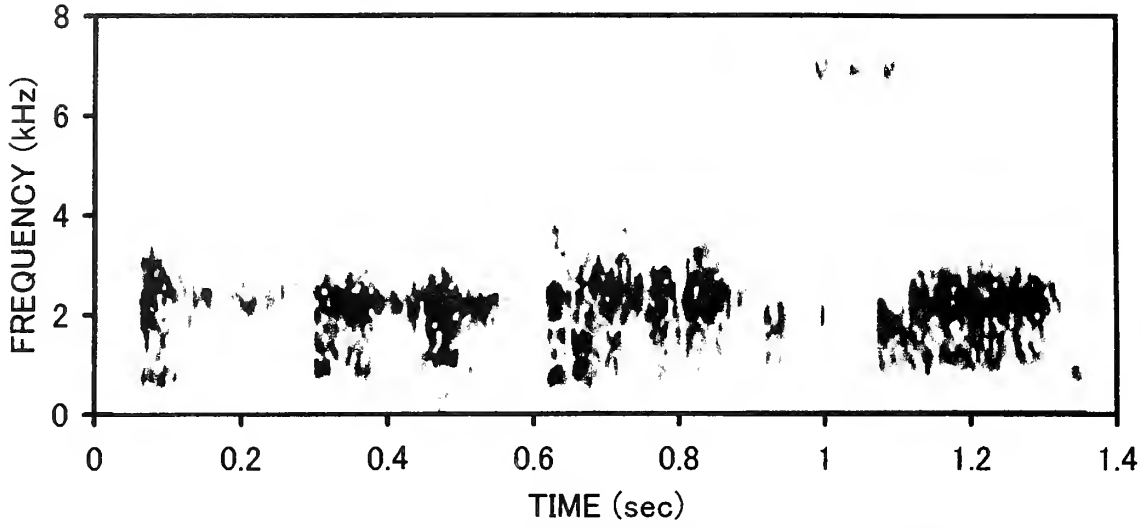

Fig. 6: Encounter calls of *Ramanella obscura* (Günther) in breeding aggregations

band of about 0.75 kHz. The calls were emitted at about 0.96 sec intervals.

In breeding aggregations where many males were heard calling in close proximity, higher frequencies became evident (Fig. 6). This call is apparently an encounter call, which has an agonistic function.

Ramanella obscura resembled *R. montana* in call duration and frequency constitution, but differed in the number of pulses. Regarding the number of pulses, the call of *R. obscura* resembled the multi-pulse call of *R. montana* (Fig. 5b). *Ramanella nagaoi* Manamendra-Arachchi and Pethiyagoda, another Sri Lankan species for which acoustic data are available, has a completely different call (Manamendra-Arachchi and Pethiyagoda 2001).

No voucher specimens.

ACKNOWLEDGEMENTS

We thank P.K. Bhat and T.B.R. Hegde for their help in the field.

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POPULATION STATUS AND CONSERVATION OF HOOLOCK GIBBONS *HYLOBATES HOOLOCK* HARLAN 1834 IN BANGLADESH[1]

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Hoolock Gibbon (*Hylobates hoolock* Harlan 1834) is the only ape that occurs in the Indian subcontinent. The species is classified as endangered and their numbers have declined throughout their geographic range primarily due to habitat destruction. We determined the current status of the Hoolock Gibbons in Bangladesh. A total of 35 sites (10 in the north-eastern region and 25 in the south-eastern region) were surveyed for Hoolock Gibbons from 2002 to 2005. A total of 282 Hoolock Gibbons in 96 groups was estimated to live in 24 of the 35 sites visited. Several sites have lost all their Hoolock Gibbons within the last 15 years. Karnafuli (part of Kaptai National Park) in the south-east and Lawachara National Park in the north-east were recognised as two major strongholds of Hoolock Gibbons. Conservation of the remaining Hoolock Gibbons of Bangladesh rests on the future management of their patchy forest habitats. We recommend the cessation of illegal deforestation, habitat restoration and translocation of individuals to maintain these last Hoolock Gibbon populations in Bangladesh.

Key words: Hoolock Gibbon, *Hylobates hoolock*, status, conservation, Bangladesh

INTRODUCTION

Gibbons are socially monogamous small apes that hold a very important position in the ecology of tropical forests (Preuschoft *et al.* 1984; Chivers 2001). They have been under considerable threat primarily due to habitat destruction throughout their range. Among the 13 gibbon species, Hoolock Gibbons *Hylobates hoolock* are the only ones that occur within the Indian subcontinent and are perhaps under the greatest threat throughout their geographic range (Mootnick *et al.* 1987; MacKinnon and MacKinnon 1987; Islam and Feeroz 1992; Feeroz 1999, 2001; Choudhury 2001). Habitat destruction is the principal cause of population decline (Gittins and Akonda 1982; Gittins 1984; Gittins and Tilson 1984; Chivers 2001; Islam *et al.* 2004). They are distributed in various north-eastern states in India, with a current total population of more than 2,600 individuals (Molur *et al.* 2005). Their distribution in southern China and Myanmar is recognised, but population estimates are from the 1980s (Mootnick *et al.* 1987; MacKinnon and MacKinnon 1987). In Bangladesh, Hoolock Gibbon populations were estimated to be around 3,000 individuals in the mid 1980s (Gittins and Akonda 1982). This number had subsequently crashed to about 200 individuals in the 1990s (Feeroz and Islam 1992). The declining trend continued in many areas of Bangladesh, with some areas having lost all of its Hoolock Gibbons (Feeroz 2001; Das *et al.* 2003; Islam *et al.* 2004). The observed decline are concomitant with the ongoing deforestation throughout the country's forested areas (Gain 2002). Hoolock Gibbons are apparently holding on tenaciously to some last extant forests in Bangladesh. Currently, the species are globally endangered (IUCN 2004) and in Bangladesh, they are classified as Critically Endangered (IUCN 2000).

Assessing the number of Hoolock Gibbons is a key to the understanding of their status and for developing a conservation plan to prevent extinction of the species. Generally, assessing primate populations is a difficult task that invariably leads to inaccurate estimates (Ross and Reeve 2003; Nijman 2004). This is particularly true for gibbon species, due to the fact that they use the forest canopy for movement and foraging (O'Brien *et al.* 2004). The objective of this study was to determine the population status of Hoolock Gibbons, in all the remaining habitats.

STUDY AREA

The present study was conducted in all the known Hoolock Gibbon habitats in Bangladesh, along with some habitats previously not surveyed. Thirty-five sites were surveyed (Fig. 1). The north-eastern and south-eastern regions of Bangladesh consist of semi-deciduous and moist evergreen forest patches with a wide variety of tree species (Rashid 1991; Ahsan 2001). Each region has its distinct tree composition and forest canopy characteristics (Ahsan 2001).

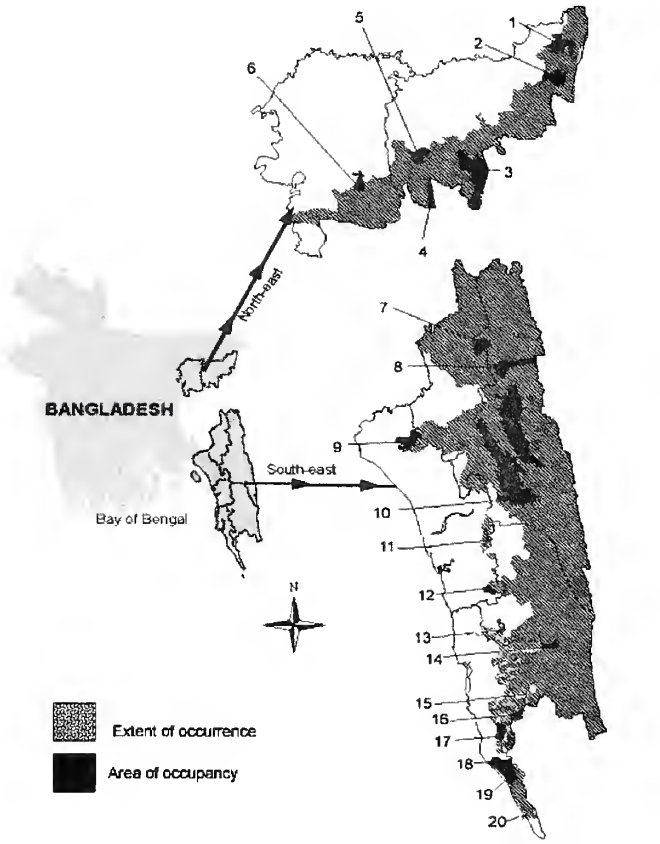

Fig.1: Hoolock Gibbon survey sites in Bangladesh. Some sites are combined due to their close proximity.
1. Baralekha, 2. Lathitila, Sagarnal, 3. Adampur, Gazipur Tea Estate, Horinchara, 4. Rema-Kalenga, 5. Lawachara, Chautoli, 6. Satchari, 7. Dighinala, Ramgar, 8. Pablakhali, Kudhukhoza, 9. Korerhat, Hazarikhil, 10. Rampahar, Karnafuli,(Kaptai) 11. Dopachari, 12. Chunati, Satghar, 13. Bamu, 14. Thanchi, 15. Alikadam, 16. Sangu, 17. Fashiakhali, Bhomarighona, Bangdepa, Bishari, Rajghat, Apar Rezu, 18. Inani, 19. Ukhia, 20.Teknaf.

Ten sites were identified from the north-eastern region (Fig. 1 and Table 1). Most of the sites fall under the jurisdiction of different forest divisions and have suffered extensive deforestation over the last two decades (Gain 2002). However, many of the sites contain habitats that may be regarded as suitable for Hoolock Gibbons (Feeroz 1999, 2001; Islam *et al.* 2004, 2006).

METHODOLOGY

At each site, locals were consulted for identifying possible locations of Hoolock Gibbon groups. One local guide was taken and existing paths within the forest patch or streams were walked on by a team of 2-4 individuals. The team conducted census walks between 0500 and 1730 hours with a total of two hours break throughout the entire period. Every 5-10 minutes the members of the team would stop to look around for signs of Hoolock Gibbon presence. This included hearing of calls; scanning the tree line with binoculars for Hoolock Gibbons in the canopy; looking for important fruiting trees (such as species of *Artocarpus* and *Ficus* etc.). When calls were heard, an attempt was made to assess the direction of the call and then to locate the group. Once located, the age-sex structure of the group was ascertained, with the assignment of each individual to either adult male, adult female, subadult male, subadult female, subadult (undetermined sex), juvenile or infant following Feeroz (1991) and Ahsan (1994). When counting Hoolock Gibbons in high-density areas (such as Lawachara and Kaptai), extra time and effort was given to ensure that double counts were not made by visiting the sites repeatedly and ascertaining numbers and age-sex structure. The coordinates of the encounter sites were determined using a hand-held Global Positioning System (GPS). The GPS coordinates were recorded into a computer and the locations of the groups plotted on digital and paper maps of the area. When the group could not be located, the group size was conservatively assumed to be two individuals and the coordinates were recorded, along with the direction and approximate distance from the calling group. The total distance travelled during walks was estimated from the GPS readings of the starting and ending points, and from the GPS coordinates taken from various locations during the census walk (including those of Hoolock Gibbon encounters).

RESULTS AND DISCUSSION

Two hundred and fifty eight Hoolock Gibbons in 80 groups were recorded during this survey at all the sites (Table 1). Additionally, 12 distinct groups with an estimated 24 individuals were heard calling, making the total population to be an estimated 282 individuals in 92 groups.

It is clear that Hoolock Gibbon populations have undergone massive decline since the 1980s, primarily due to habitat destruction, although they continue to survive in small pockets of fragmented forests in Bangladesh. The largest population in the north-eastern region is in Lawachara National Park, within west Bhanugach Reserve Forest (Table 1). Additional populations in Adampur and Baralekha are of importance, each having larger than or equal to ten individuals, assumed to be required for long-term viability (IUCN 1994; Islam *et al.* 2006). In recent years, the south-eastern region had been deemed unsuitable for Hoolock Gibbons due to acute habitat loss and political unrest (Gain 2002; Islam *et al.* 2004). We identified Karnafuli (within Kaptai Forest range), a series of highly fragmented secondary

Table 1: Hoolock Gibbon (HG) populations recorded at 35 sites during 2002-2005 (based on observed groups and calling groups)

Sites	Days of counting	Groups counted	Individuals counted	Groups calling	Numbers calling[a]	Estimated groups[b]	Estimated numbers[c]
North-east (10 sites)							
Baralekha	9	3	10			3	10
Lathitila	2	1	5	2	4	5	9
Shagarnal	2	0		1	2	1	2
Gazipur Tea Estate	6						
Lawachara NP	40	11	42			11	42
Chautoli	2	1	4			1	4
Adampur	13	8	21			8	21
Horinchara	6						
Rema-Kalenga WLS	8	2	2			2	2
Satchari NP	11	2	7			2	7
South-east (25 sites)							
Dighinala	7	1	2			1	2
Pablakhali WLS	7	1	4			1	4
Ramgar	6						
Korerhat	6						
Hazarikhil WLS	8	1	4			1	4
Bishari	2	2	8			2	8
Bengdepa	2	2	7	1	2	3	9
Karnafuli (Kaptai NP)	27	23	78	3	6	26	84
Rampahar (Kaptai NP)	9	4	14	1	2	5	16
Chunati WLS	11						
Satghar	6						
Fashiakhali	6						
Bamu	5	4	14			4	14
Thanchi (Tindu mouza)	2	2	4	1	2	3	6
Khudhukoza	1	2	5			2	5
Dopachari	3	2	5	1	2	3	7
Sangu	1	1	2			1	2
Alikadam	2						
Rajghat	1			1	2	2	2
Bhomarighona	8						
Himchari NP	7						
Inani	8	2	6			2	6
Ukhia (Thankhali)	9	5	14			5	14
Teknaf GR	6			1	2	2	2
Upper Rezu	1						
TOTAL	250	80	258	12	24	96	282

a. number of HG groups calling x 2 (individuals/group)
b. number of HG groups counted + number of HG groups calling.
c. number of HG individuals seen + estimated number of HG calling

forest patches, having sufficient habitat to hold large number of Hoolock Gibbons (Islam *et al.* 2004). Extended monitoring activity in the area revealed the largest stronghold of Hoolock Gibbons in the country with 84 individuals. Rampahar Beat (also within Kaptai Range), slightly separated from Karnafuli was noted to have 16 individuals, further increasing the number of Hoolock Gibbons in the area.

The rest of the scattered populations of less than 9 individuals vary in terms of importance. Some have been evaluated entirely (e.g. Lathitila, Rema-Kalenga, north-east; and Dighinala, Pablakhali, Hazarikhil, Teknaf, south-east) and are unlikely to have any more individuals. Other populations have not been surveyed adequately (e.g. Thanchi, Kudhukoza, Dopachari, Sangu, all in the south-east) and more thorough surveys in these areas could yield more Hoolock Gibbons, although the south-eastern region, in general, has had a more

devastating history of deforestation (Gain 2002).

The "forested lands" administered by Bangladesh officially represent about 17% of the total land area of Bangladesh, although the true area of forest cover is likely to be less than 6% (Gain 2002). Within the forestlands, there are about 16 protected areas categorised into National Parks, Wildlife Sanctuaries or Game Reserves (Kabir and Muzaffar 2002). These protected areas are recognised merely on paper. Illegal harvesting of forest products (timber, fuel wood etc.) continues unabated, often in connivance with the forest officials. Most of the areas within protected forest patches are fragmented and have areas of agricultural land, small villages, grazing land and other human altered habitats that make the quality of these areas extremely poor. In spite of all these major habitat problems, the Hoolock Gibbons present in various protected and unprotected forest patches show extraordinary resilience. The minimum assumed viable population of Gibbons is 10 individuals (IUCN 1994) and this is supported to a certain extent by mathematical models (Molur *et al.* 2005; Islam *et al.* 2006). Many of the populations noted in this study are much smaller in size than this theoretically viable minimum and thereby regarded as genetically destined to extinction.

Immediate cessation of deforestation in all the areas above is required. Since this is very difficult to accomplish given the socio-political dynamics of each region, at least safe-guarding the important fruiting and sleeping trees, along with protection of some closed canopy forest patches is essential (Islam *et al.* 2006). To supplement the protection and preservation of forests, habitat improvement and restoration in many of these areas should be done. Plantation of mixed fruiting tree species may be carried out on a large scale to attempt to restore degraded habitat where suitable. Careful examination of all areas with Hoolock Gibbons is also needed to assess the feasibility of translocation of doomed Gibbon populations into areas that are doing relatively better. Populations such as the single Gibbon in Rema-Kalenga and the few odd individuals each in Shagarnal, Hazarikhil, Teknaf, Inani and Himchari may have a better chance of survival if moved to areas with better habitat (e.g. Satchari in the north-east, and Bamu and Ukhia in the south-east). These manipulative methods may be the only hope for these individuals and need to be seriously considered.

We conclude that the total population of Hoolock Gibbons in Bangladesh in the current estimate is higher than that made in the nineties (around 200 individuals, Feeroz and Islam 1992). However, many of the previously important sites (e.g. Horinchara, Chunati) are now devoid of Hoolock Gibbons and this is cause for great concern. Conservation action should be directed towards protecting the remaining Hoolock Gibbon strongholds from further degradation, translocating genetically compromised populations and restoring forest lands through plantations of mixed native plant species (Islam *et al.* 2006). Public awareness is on the rise and the Government of Bangladesh is a signatory to various biodiversity conventions, the future could hold some promise if immediate action is taken in attempting to save the remaining Hoolock Gibbons.

ACKNOWLEDGEMENTS

We thank the US Fish and Wildlife Service for funding this project through its Great Ape Conservation Program. We are grateful to the Forest Department of the Government of Bangladesh for access and accommodation at many of the study sites. The work would have been impossible without the efforts of many students and volunteers. We thank the Departments of Zoology, Jahangirnagar University and the University of Dhaka; and the School of Environmental Science and Management of Independent University, Bangladesh for permitting and facilitating research activities at different study sites.

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RANGING AND HABITAT SELECTION BY ASIAN ELEPHANTS *ELEPHAS MAXIMUS* IN RAJAJI NATIONAL PARK, NORTH-WEST INDIA[1]

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We collected data on Asiatic Elephant *Elephas maximus* ranging and habitat selection in Rajaji National Park (RNP) in Uttarakhand state, India using radio telemetry from December 1996-March 1998. Elephant home ranges were estimated (using 100% Minimum Convex Polygon) to range from 188 sq. km to > 400 sq. km. We could not detect any difference between male and female home ranges. Summer ranges were the smallest due to limited availability of water in the study area; however, we could not detect statistically significant differences between sexes or seasons. The six Elephants that were radio-tracked for over two years showed variability in ranging patterns between the 1st and the 2nd years. The overall Elephant population used the *Shorea* vegetation significantly less than the other major vegetation types (*Shorea*-mixed, Miscellaneous and Mixed plantations). This was due to the higher diversity of Elephant food plants in *Shorea*-mixed and miscellaneous vegetation types when compared to *Shorea* vegetation type. However, radio-tracking data from individual female Elephants that had young calves at heel indicated a strong preference for the *Shorea* vegetation type. This was due to the fact that very few species, which can be lopped as fodder for cattle, were found in the *Shorea* vegetation type and thus had fewer disturbances that made it attractive for females with young calves. Thus, females with young calves clearly preferred to trade off food for safety. The mean cattle densities in the home ranges of radio collared females, who were either pregnant or had young calves at heel, were significantly lower when compared to that of male home ranges. This study has proven beyond doubt that a major influence on ranging and habitat use in the study population is disturbance.

Key words: Asian Elephants, *Elephas maximus*, ranging, home-range, radio-tracking

INTRODUCTION

The size of an elephant's home range gives an indication of the availability of essential resources, restrictions imposed by the size of the respective conservation area or other artificial barriers and the degree of disturbance to which the animal is exposed (Whyte 1996). Areas with plentiful food and water, and minimal disturbance will have smaller home ranges. It can also be small where artificial barriers (e.g. dams, canals and habitat loss due to agricultural settlements in corridor areas) prevent elephants from using a part of their home ranges (Joshua and Johnsingh 1995). It is important from the management point of view to know which elephant groups/ clans have been affected due to such developments because concentration of elephants in a restricted area could also lead to habitat degradation. In several cases, the ecological boundaries and administrative boundaries do not match (Joshua and Johnsingh 1995) and knowledge of elephant movements is critical for preparing management plans in such an area. In addition to crucial information about home ranges, it is also important to understand the foraging behaviour and spatial use of the resources within the home range.

To collect data on the above aspects, Elephants in Rajaji National Park (RNP) have been intensively studied since December 1996 using radio telemetry. Rajaji National Park in conjunction with Corbett Tiger Reserve and the adjoining forest areas have been designated as one of the eleven elephant reserves in India. An estimated population of about 1000 Elephants is found within this tract (Singh 1995). The Elephants in this area have been under assault from human induced causes, such as diversion of land for non-forestry purposes, over-grazing and excessive lopping of trees for fodder, construction of a canal and, road and rail network resulting in habitat fragmentation (Johnsingh *et al.* 1990). RNP, due to its linear shape, has a long boundary, with a sizeable pastoral Gujjar population inside and villages all around the periphery. The main livelihood of the villagers is agriculture. Therefore, to ensure the long-term survival of Elephants, a thorough understanding of their ranging and habitat requirements is indispensable. We conducted a study on Elephants and their habitats with the following objectives:

1. To describe and explain the ranging behaviour of Elephants in the study area and,

2. To analyze seasonal use of vegetation types by

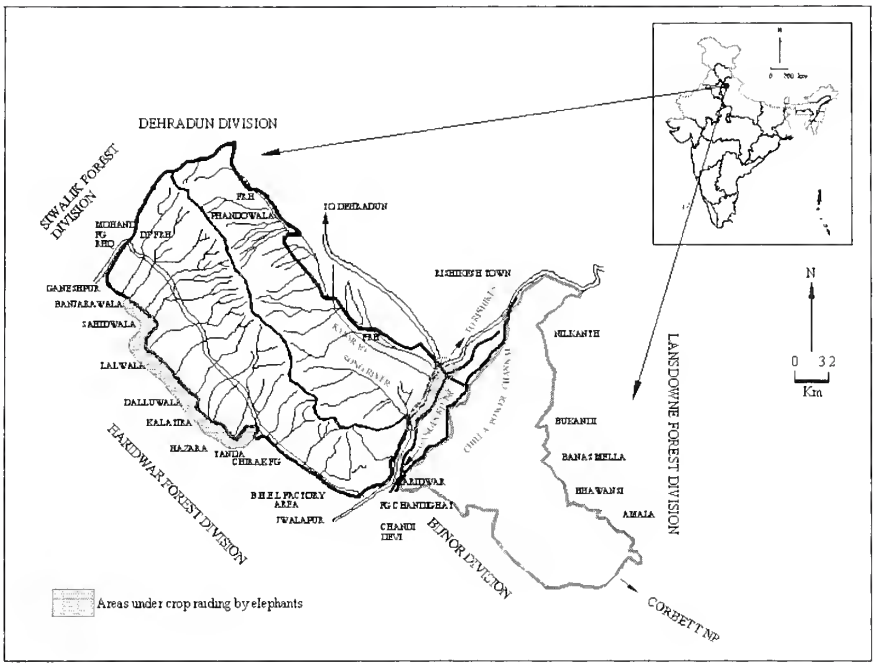

Fig. 1: Map of Rajaji National Park

elephants within the study area and to identify the major factors influencing habitat selection

STUDY AREA

The study was conducted in Rajaji National Park (RNP) west of the River Ganga (Fig. 1). The area includes the Rajaji and Motichur sanctuaries and portions of the Siwalik and Dehradun East Forest Divisions covering an area of approximately 600 sq. km. Topography in the Rajaji Sanctuary area consists of deeply dissected steep southern slopes of the Siwalik hill range, which form a series of sharp ridges interspersed with V-shaped valleys running from north-east to south-west. The southern portion of the Sanctuary is flat land constituting the northern fringe of the Gangetic plain. The altitude ranges from 400 to 1,000 m. There are >4,000 nomadic pastoralists (i.e. Gujjars) and about 8,300 of their livestock (e.g. buffalo, goat etc.) within the study area. These Gujjars are dispersed throughout the study area in small settlements. Over 1,40,000 people live along the periphery of the study area. Their main form of livelihood is agriculture. The study area is bounded by intense cultivation to the north and south, and to the east it is bounded by the suburbs of the town of Haridwar on the bank of the River Ganga. To the west, the Delhi-Dehradun highway separates the Rajaji NP from the Siwalik Forest Division.

Rainfall ranged from 1,300 to 1,900 mm / year during 1996-1999, with most of the rain falling during the monsoon months of July to October. However, there are brief periods of rainfall throughout the year. Three distinct seasons are recognised: winter (November to March), summer (April to June) and monsoon (July to October).

MATERIAL AND METHODS

Four male and four female Elephants were immobilized with Immobilon (a mixture of Etorphine hydrochloride and Acepromazine) delivered with a dart gun, and fitted with radio transmitters embedded on an acrylic collar in Rajaji National Park (Fig. 1). We radio-tracked three males and four females for periods ranging from 1 to 3 years. The Elephants were located 1 to 3 times per week. All animals were located by homing in on the signal and a GPS was used to take a position. All the data was entered into a lotus spread sheet.

We acquired satellite images of approximately of 200 x 200 m resolution and did unsupervised classification using ERDAS IMAGINE (ESRI Inc.) image analysis software. The initial output consisted of 10 different categories of land use as defined by their reflectance values. We then supervised classification and specified five major categories

of land use/Forest types. The whole study area was divided into 2 x 2 km grids and 5 random grids were chosen in each of the four categories, which corresponded to the different vegetation/forest type. In these grids, we placed a 2.8 km transect along the diagonals in each grid that had the best access. Along each transect, we measured trees in 10 m radius circular plots every 300 m. For each tree >20 cm diameter at breast height (dbh) within the circular plot, we noted the species and number of branches cut. We also counted the saplings (< 20 cm dbh) of the different tree species in a 5 m circular plot centered within the 10 m circular plot. We then summarised the data to define the four major vegetation types. They were: Sal *Shorea robusta* vegetation, Sal mixed vegetation, Plantation, Miscellaneous vegetation type, Agriculture and, open areas/degraded scrub/rau (dry river beds).

The vegetation types defined here corresponded very closely with the tree species communities defined during an earlier analysis of data, using program TWINSPAN (Two Way INdicator SPecies ANalysis), collected in the study area using similar methods. We chose to limit our analysis to these four major broad vegetation types due to the large home ranges of Elephants in the study area and due to the difficulty in identifying fine differences in vegetation composition in the field.

We then imported the land use/vegetation image into ARCVIEW 3.02a (ESRI Inc.) GIS software to analyze the data on animal locations, Gujjar cattle densities and other information like water availability. We used the ARCVIEW extension ANIMAL MOVEMENT ANALYST (Hooge and Eichenlaub 1997) to analyse the radiolocation data of the seven Elephants. Animal home ranges were defined by 100% Minimum Convex Polygons (MCP) (Mohr 1947) and 95% Fixed Kernels (Worton 1989) of all the locations pooled across seasons and years. MCP method was used so that comparisons of elephant home ranges from other studies could be done. To look at seasonal ranging and habitat use by individual elephants, we used 95% Fixed Kernels (FK) of the seasonal data. We used original Adhoc and LSCV smoothing parameters to provide a less biased estimator than a user selected or Worton's corrections (Hooge and Eichenlaub 1997). We carried out regression analysis of the % increase in home range against the number of locations to see if adequate sampling had been done to describe the seasonal range of the elephant(s).

We plotted the nomadic pastoral habitats within the study area with the help of a hand held GPS (Magellan Trailblazer, Magellan Inc.) and counted the number of pastoralists and their livestock in each of the habitats. We plotted the data and analysed it using ARCVIEW SPATIAL ANALYST extension and created cattle density maps of the study area over which we overlaid the seasonal ranges to calculate the cattle densities within each Elephant's seasonal range.

RESULTS

We captured and collared four adult male and four adult female Elephants between December 1996 and March 1998. One of the collared males was followed only for five months, and hence the data was not used for analysis. The remaining seven animals were followed for periods ranging from ten months to over three years (Table 1). Since the data beyond two years did not significantly add new information to what was analyzed after two years of tracking, we chose to use only 24 months of data to understand the habitat use patterns. The number of collared males represented approximately 10% of the estimated adult male population size in the study area (Williams *et al.* 2007). Female Elephants live in groups of related females and their associated young. Females and young associated with groups containing the collared females represented approximately 33% of the total estimated female and associated young population numbers (Williams *et al.* 2007). The radio-tracked individuals ranged over an area of about 600 sq. km (Fig. 2). Little dung (<1%) was encountered outside this area during the dung surveys, indicating that the entire elephant population (*c.* 180-200) west of the River Ganga largely used this 600 sq. km. However, there were cases of elephant bulls and family groups straying towards Yamuna in the Siwalik Forest Division (Fig. 1). On eastern side, only a few bulls crossed over the Ganges through the Chilla-Motichur corridor. Females did not cross the Rishikesh-Haridwar road.

Ranging

Minimum number of location needed

For the study animals, since ranging and habitat use within a season was of interest, it was necessary to find the

Table 1: Annual home ranges (sq. km) of radio-tracked elephants as calculated by the minimum convex polygon method (MCP) in Rajaji National Park, 1996-2001

Animal ID	No. of locations	No. of months tracked	Home range (MCP)
MaleT	253	24	407.04
MaleS	285	24	188.04
MaleA	123	10	254.72
FemaleM	233	21	183.96
FemaleA	235	24	326.64
FemaleD	211	24	306.28
FemaleK	264	24	251.6

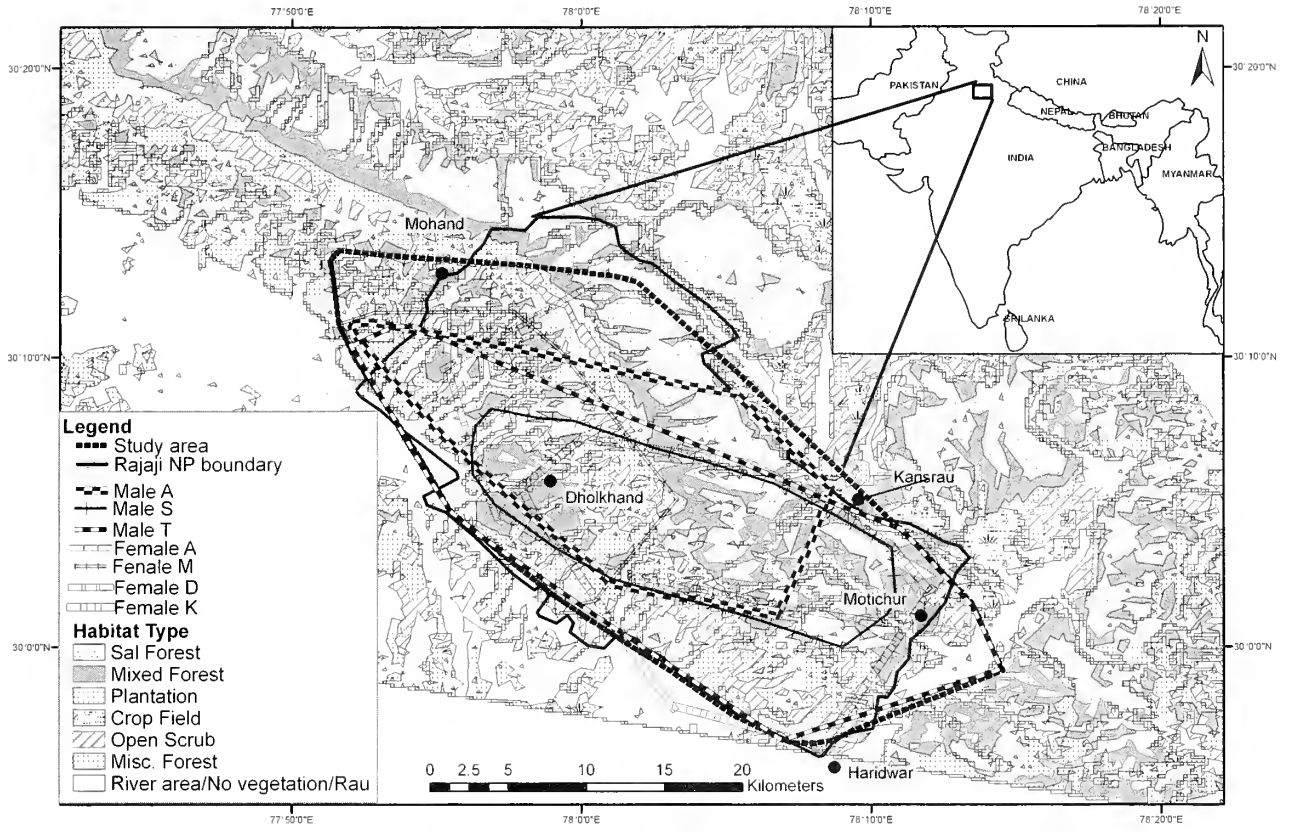

Fig. 2: Home ranges (100% MCP) of the radio collared elephants within the study area

minimum number of locations needed to be sure that the seasonal range had been well described. The relationship between mean percent change in home range estimates and the number of locations needed was asymptotic (Fig. 3). The minimum number of locations needed to estimate fairly accurate seasonal home ranges should have at least two characteristics (Mares *et al.* 1980).

1) All the intervals past the minimum estimate should have mean percent changes in home ranges that are indistinguishable from zero;

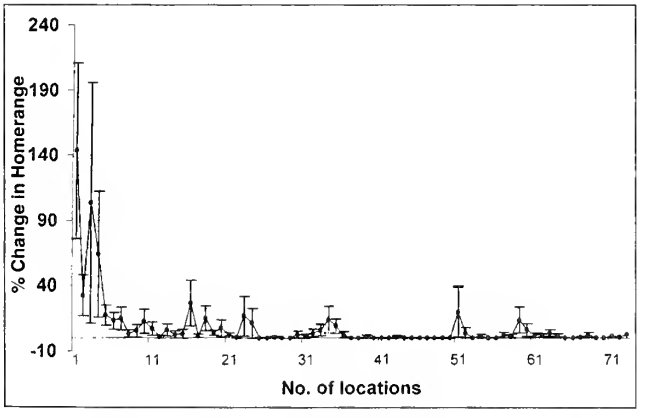

Fig. 3: Mean and SE of % change in home ranges (N=7 elephants) with successive locations

2) A constant relationship should exist for all locations intervals past the minimum estimate (i.e. a regression line whose slope is zero should exist).

Both of these criteria were met for Elephants at between 20 and 30 relocations per season (Fig. 3). The mean ±1 SE for all points between 20 and 30 locations contain zero and an insignificant linear relationship (Table 2) exists for data points greater than the 25th location (i.e. the slope of the regression line is not statistically distinguishable from zero).

Annual and seasonal range estimates

Elephants had home ranges (100% MCP) from 188 sq. km to >400 sq. km (Table 1). However, there seems to be no difference in annual home ranges between males and females. There was large variability in the seasonal ranges between elephants, seasons, and years (Table 3). There were no

Table 2: Linear regression in an ANOVA setting (Excel spreadsheet function); mean percent change in home range as a function of number of locations

Source of variation	df	SS	MS	F	P
Due to regression	1	0.1569	0.1569	0.160	0.690
Residual	47	45.98252	0.9783		
Total	48	46.13942			
Multiple r^2 = 0.003401					

difference in ranges between seasons when pooled across sexes and years (Kruskal-Wallis one way ANOVA, $\chi^2 = 1.7709$, 2 df , $P = 0.41$). Summer ranges (95% FK) were the smallest of the three seasons (Table 4). Males had larger summer seasonal ranges than females (Mann-Whitney test, $U = 2.0$, $P = 0.01$). There was no difference in the seasonal ranges between male and female elephants in winter and monsoon. All the 6 elephants (2 males and 4 females) that were tracked for 2 annual cycles showed variability in ranging patterns between the 1st and 2nd years. Summer ranges were rather small or linear in shape when compared to the ranges of the same individual or group for monsoon and winter. For example, Male T and Female A ranged more widely in the monsoon of 1998 when compared to the same season in the previous year (Tables 3 & 4). The MCP estimates in Table 3 were better suited at reflecting occasional wandering by the Elephants than the 95% FK estimates in Table 4. Hence, the following section refers mainly to estimates from Table 3. Males T and A came into musth in winter while Male S came into musth in summer. All the males consistently used large ranges during their musth period and were wandering widely (Table 3). Females M and D gave birth to calves in 1997 and 1998 monsoon season respectively. Their seasonal ranges in winter and summer following calving were approximately 25 to 50% of their seasonal ranges the previous year (Table 3). There was a vast difference in ranging patterns of the female M and her group between the two years that they were tracked. In the year 1998-99, she altogether abandoned the southern side of the Park and spent the entire period in the northern half of the Park before being run over and killed in a train accident near the main road on the east.

Female D exhibited similar behaviour by spending most of the time in areas of fewer disturbances during winter and summer following the birth of her calf. However, her monsoon ranging pattern remained unchanged.

Seasonal use of vegetation types

Males avoided the use of *Shorea* forests during winter and monsoon, and to a large extent used the other vegetation types in proportion to their availability (Table 5). Females, on the other hand, used the mixed-plantations, miscellaneous vegetation, open degraded scrub and riverbeds (Table 5) less than expected. Females (M, D and K) which were either pregnant or had young calves at heel during the period that they were radio tracked showed either strong selection or avoidance of vegetation types (Table 7). *Shorea*-mixed vegetation type was either selected or used in proportion to availability by all the females (Table 5). All the Elephants

Table 3: Seasonal home ranges (sq. km) of elephants calculated by the Minimum Convex Polygon method (MCP) in the various seasons in Rajaji National Park (1996-1999)

Year/Animal	Season					
	Winter (Nov.-Mar.)		Summer (Apr.-Jun.)		Monsoon (Jul.-Oct.)	
	No. of locations	MCP	No. of locations	MCP	No. of locations	MCP
1996-97						
MaleT	53	248.92	29	86.60	39	148.52
MaleS	51	74.56	33	79.12	50	78.64
FemaleM	50	90.28	24	84.24	40	83.32
FemaleA	32	110.4	36	57.24	35	37.12
FemaleD					45	114.36
FemaleK					48	136.96
1997-98						
MaleT	71	307.68	32	181.00	29	257.84
MaleS	72	53.48	32	112.44	47	84.12
MaleA			50	52.32	55	124.28
FemaleM	53	46.92	36	26.00	30	63.12
FemaleA	64	65.96	30	72.76	38	147.4
FemaleD	54	208.12	25	42.84	28	139.36
FemaleK	67	129.48	37	98.24	31	145.60
1998-99						
MaleA	18	192.6				
FemaleD	42	52.48	17	17.2		
FemaleK	59	152.32	22	27.32		

avoided *Shorea* forests during the 1997 monsoon (Table 5). The same ranging pattern was observed in the monsoon of 1998, when the Elephants largely avoided *Shorea* forest, except for females D and M which had young calves at heel.

Human and cattle densities within the study area were highly correlated (Spearman's r = 0.66, P<0.0001, n=321). Hence, we used only cattle densities as an index of disturbance. The density of cattle was higher inside the home ranges of collared males when compared to that of collared females (Table 6). Only Female K tolerated disturbance (as measured by cattle densities) at levels tolerated by males in the monsoon season (Table 6). If the monsoon season was excluded from the analysis, the mean cattle density in the home ranges of females (K, D & M) that were pregnant or had young calves at heel was much lower when compared to the males (Table 6). However, Female A, which was neither visibly pregnant nor had a young calf at heel, used areas with disturbance comparable to the area with cattle density (mean = 27.7 cattle/sq. km and S.D.=1.5) used by males.

The densities of important food plants of Elephants were highest in *Shorea* vegetation type (Table 7). Even when *Shorea* was excluded from the plants considered, *Shorea* vegetation type still had the highest densities of important elephant food plants (Table 7), and this was mainly due to the contribution of *Mallotus phillippensis*. However, *Shorea* was the least used among the vegetation types (Table 5), except for females that had young calves at heel. When we looked at diversity and density of major elephant food plants in the four vegetation types, *Shorea*-mixed and miscellaneous vegetation type had the highest diversity of elephant food plants.

Water was available everywhere during the monsoon season and therefore, we did not consider the monsoon season when testing for differences between seasons. We could not detect a statistical difference in the distance to water between winter (Mean ± SE=1,311.69 ±83.59) and summer (Mean ± SE = 1,299 ± 41.48) seasons pooled across animals (T = 0.13, df = 17 , P = 0.89) and years.

DISCUSSION

Ranging and habitat use by elephants have been studied before in African and Asian elephant populations (Douglas-Hamilton 1972; De Villiers and Kok 1997; Baskaran *et al.*

Table 4: Seasonal home ranges (sq. km) of elephants calculated as 95% fixed kernels (FK) in the various seasons in Rajaji National Park (1996-1999)

Year/Animal	Season					
	Winter (Nov.-Mar.)		Summer (Apr.-Jun.)		Monsoon (Jul.-Oct.)	
	No. of locations	FK	No. of locations	FK	No. of locations	FK
1996-97						
MaleT	53	281.04	29	142.48	39	71.6
MaleS	51	52.36	33	125.04	50	108.48
FemaleM	50	49.0	24	69.4	40	48.96
FemaleA	32	79.36	36	70.36	35	53.92
FemaleD					45	181.32
FemaleK					48	30.76
1997-98						
MaleT	71	239.84	32	181.24	29	405.2
MaleS	72	66.16	32	190.92	47	144.84
MaleA			50	72.12	55	146.2
FemaleM	53	60.16	36	23.96	30	69.24
FemaleA	64	109.12	30	80.4	38	180.2
FemaleD	54	209.28	25	83.2	28	175.72
FemaleK	67	169.0	37	53.48	31	67.84
1998-99						
MaleA	18	349.68				
FemaleD	42	130.0	17	33.6		
FemaleK	59	208.92	22	33.6		
Mean		154.15		94.65		129.56
SE		27.05		15.37		27.40

Table 5: Selection and Avoidance of the vegetation associations by elephants in Rajaji National Park

Season/Animal	No.	χ^2	Vegetation association[a]				
			Shorea	*Shorea*-mix	Mixed-plantations	Miscellaneous	Others[b]
Males							
1996-97 Winter							
MaleT	53	13.1	A				
MaleS	51	16.42	A				
1997-98 Winter							
MaleT	71	19.17	A				S
MaleS	72	26.25	A				
1997 Summer							
MaleT	29	10.94		A			
MaleS	33	8.93					
1998 Summer							
MaleT	32	7.73					
MaleS	32	8.62					
MaleA	50	11.62					
1997 Monsoon							
MaleT	39	44.54	A	A		S	
MaleS	50	9.75					
1998 Monsoon							
MaleT	29	18.02	A				
MaleS	47	10.27	A				
MaleA	55	6.16	N				
Females							
1996-97 Winter							
FemaleM	50	5.62					
FemaleA	32	6.65					
1997-98 Winter							
FemaleM	53	41.29	S	S	A	A	A
FemaleA	64	11.76	A				
FemaleD	54	17.19					A
FemaleK	67	7.41					
1998-99 Winter							
FemaleD	42	46.6	S		A	A	A
FemaleK	59	9.78					
1997 Summer							
FemaleM	24	20.62		S	A		
FemaleA	36	0.81					
1998 Summer							
FemaleM	36	12.82			A		
FemaleA	30	4.82					
FemaleD	25	20.48	S		A	A	
FemaleK	37	17.68					
1999 Summer							
FemaleD	17	30.94			A	A	
FemaleK	22	10.25					
1997 Monsoon							
FemaleM	40	18.64	A				A
FemaleA	35	22.48	A			S	
FemaleD	45	8.97					
FemaleK	35	22.48	A	A			
1998 Monsoon							
FemaleM	30	32.83	S		A		A
FemaleA	38	7.5					
FemaleD	28	14.44			A		
FemaleK	31	9.42	A				

[a]S = association use > expected; A = association use < expected; N = no use of the habitat recorded; blank cells = association use proportional to availability (P = 0.05) (Byers *et al.* 1984);

[b] = includes open scrub, grasslands and river beds.

1995; Mckay 1973). This is the first study in Asia where the proportion of elephants, for whom ranges have been described, has been reported (see results). After this study, we have an accurate and fairly descriptive measure of the ranging patterns of adult males and female groups in RNP. Most of the elephant ranging seems to be confined to the National Park boundaries to the west of River Ganga unlike on the other side, where Joshua and Johnsingh (1995) found that 40-60% of two elephants home ranges were outside the RNP area boundary. There seems to be very few groups using the Siwalik Forest Division. However, as the densities inside the Park increase more and more elephants will start using areas outside, such as the Siwalik and Dehradun Forest divisions. The population seems to be a closed one; we could find evidence for only about 3 bulls' crossing over Ganga from Motichur to Chilla side of RNP.

Elephant home ranges recorded, so far, vary widely depending on the elephant population and the ecological conditions under which they were studied. The results from this and earlier studies (Joshua and Johnsingh 1995) indicate that adult male home ranges in RNP vary widely ranging from about 160 sq. km to over 400 sq. km. An earlier study on the Chilla side of RNP concluded that the small home range recorded (approx. 39 sq. km) for a single adult female was due to her home range being lost to developmental activity (Joshua and Johnsingh 1995). This seems to be supported by the results of our study where the smallest female home range was about 200 sq. km. Most studies on African elephants have showed a strong relationship between rainfall and home range size. Home ranges of elephants in areas of higher rainfall (Tsavo west – 750 sq. km) were smaller than the ranges of elephants in areas of low rainfall (Tsavo east – 1,600 sq. km). Thouless (1996) showed similar results from his study in northern Kenya, where the home ranges varied between 102 sq. km (high rainfall area) to 5,527 sq. km (low rainfall area). However, human disturbance also played a significant role in influencing the range sizes. The home ranges of two adult females tracked in northern Cameroon were 3,066 sq. km and 2,484 sq. km respectively (Tchamba *et al.* 1995), and it is thought that intensity of the elephant-human conflict forced the two elephants to move long distances resulting in large home ranges. De Villiers and Kok (1997) estimated, after six years of radio tracking in two nature reserves adjacent to Kruger National Park, that female home ranges varied between 115 sq. km and 342 sq. km, whereas male home ranges were between 150 sq. km and 342 sq. km. They showed that availability of water played an influencing role on the size of the elephant home ranges in the two reserves. In Asia, however, home range sizes reported (males: 160-400 sq. km; females: 40-650 sq. km) are much lower due to the elephants living in mainly forested habitats with higher rainfall than recorded across many of the African studies sites (Joshua and Johnsingh 1995; Baskaran *et al.* 1995).

Individual home ranges also overlapped considerably within and between sexes in the study area as noticed in other studies on elephants elsewhere (Leuthold 1977; Jachmann 1992; Thouless 1995; Sukumar 1991; Baskaran *et al.* 1995; Joshua and Johnsingh 1995). However, De Villiers and Kok (1997) found that females tend to avoid each other inside their core areas (defined as 10% of their home range) and explained this as a mechanism under which high densities of elephants are able to tolerate each other in a small area. The density of elephants in our study area was low (<0.4/ sq. km) compared to that of other areas (1-4/sq. km) where detailed elephant studies have been carried out. We could not carry out this analysis, since there were groups which did not have radio collared individuals overlapping with our study animals. We, however, noticed that even though three radio collared female groups were in the general vicinity during the dry season, we located them together only once in two years of tracking. There seems to be very little temporal overlap between the female groups within the study area.

The summer ranges were smaller than other seasons due to the limited availability of water in the study area

Table 6: Cattle densities (No./sq. km) in the seasonal home-ranges of male and female elephants in Rajaji National Park 1996-99

Sex	Cattle densities			
	With monsoon season		Without monsoon season	
	Mean (n)	SE	Mean	SE
Male	29.70 (15)	1.72	26.59 (10)	1.26
Female	23.71 (24)	2.94	15.88 (12)[1]	0.79
Mann-Whitney U	72		2	
P	0.0018		0.0001	

[1] = Densities calculated for females, K, D & M, that were either pregnant or had calves at heel during the study period.

Table 7: The densities (No./Ha) of important elephant forage trees in four vegetation types in Rajaji National Park

Vegetation type	Forage tree density			
	With *Shorea robusta*		Without *Shorea robusta*	
	(Mean)	SE	(Mean)	SE
Shorea	578.31	40.45	298.84	21.36
Shorea-mix	277.41	24.32	251.30	25.66
Mix-plantations	162.21	20.45	156.78	20.11
Miscellaneous	86.15	14.63	74.51	13.22

(Tables 3 & 4). Elephants showed a greater fidelity in the dry season than in the other seasons, except for Female K who showed a high degree of fidelity across all seasons. This is consistent with other studies on elephants where water was a limiting factor in Africa (Leuthold 1977; Viljoen 1989a, b; Thouless 1995).

Elephants in this area also showed a high degree of fidelity with regard to dry and wet season, which was in contrast to the elephants of Tsavo (Leuthold 1977). Another point to note in the present study was that both females D and M changed their ranging pattern from previous years immediately following the birth of a newborn calf. Thus, this study also proves that elephants show considerable flexibility in ranging behaviour to improve their chances of survival. They also had smaller dry season home ranges, a result similar to the one reported by De Villiers and Kok (1997). The temperatures in the study area rose as high as 42 °C during summer. Females remained near permanent water sources during summer, as it would probably be detrimental to the survival of calves to move widely in search of food during such temperatures. Also the females with young calves (D, M and K) used permanent water sources in areas of low disturbance.

Very few studies have reported increases in seasonal ranges due to adult males coming into *musth* (equivalent to rut) (Joshua and Johnsingh 1995). T and A came into *musth* in winter, while S came into *musth* in summer. We found that all three adult males that we followed were given to wandering widely in search of females during *musth* and consequently had large ranges during *musth* when compared to other seasons (Table 3). In rainy season of 1997-98 Male T shifted between two areas, and hence a large home range was recorded. Similarly, Joshua and Johnsingh (1995) reported that a male, which was radio-tracked for over two years, increased its seasonal range from 22 sq. km in the monsoon to over 200 sq. km in winter (it's *musth* season).

Elephants in RNP seem to use *Shorea*-mixed vegetation type much more than the other vegetation types (A. Christy Williams, unpubl data). This seems to be consistent even with selection at an individual level, where *Shorea*-mixed vegetation was the least avoided. *Shorea* vegetation had the lowest dung densities indicating minimal elephants use (A. Christy Williams, unpubl data). However, individual elephants, having young calves that were radio tracked for over two years showed strong selection for the *Shorea* vegetation. This is mainly due to the fact that very few species that can be lopped are found in this vegetation type and therefore avoided by the Gujjars to a large extent, and thus less disturbed than the other vegetation types (Williams *et al.* 2002). During the monsoon season females and males used the miscellaneous vegetation in proportion to availability or selected it in a few cases. We believe this is due to the abundance of green grasses such as *Dolichostachya* and the presence of the bamboo *Dendrocalamus strictus*, important food sources for elephants during monsoon. Elephants in the study area eat a large amount of grass in the wet season, even if they appear to like browse at other times and this seems to be consistent from other studies in Africa (Buss 1961; Field 1971; Laws *et al.* 1975). Seasonal changes in habitat selection and diet have been observed in different elephant populations across Africa and Asia (Buss 1961; Field 1971; Mckay 1973; Laws *et al.* 1975; Leuthold 1976; Olivier 1978; Barnes 1982; Sukumar 1991; Sivaganesan and Johnsingh 1995) indicating the relative opportunistic nature of the diet of elephants. They are able to utilize a wide selection of food available from ground level up to 4-5 m, and thus are able to survive even tough environmental conditions like drought and unpredictable rainfall.

The distribution and availability of water governs the distribution of elephants (Laws 1970; Kerr and Fraser 1975). Outside the monsoon season water availability in the study area is restricted to the foothills of the Siwaliks. In summer, water availability becomes restricted to small pools along the *raus*. Yet, we failed to detect any differences in distance to water between the winter and summer seasons for the study animals indicating elephants at all times used areas nearer to water.

This study has proved that a major influence on ranging and habitat use in Elephants is disturbance. Female Elephants with calves do not tolerate disturbance and females respond to disturbance by moving into areas with fewer cattle. Thus, resettling *Gujjars* outside the Park area has to be given priority and encouraged to free more areas of human disturbance. We have already seen that the Elephant population in the study area is demographically very viable (Williams *et al.* 2007) and therefore, as the elephant population increases, need for more areas with fewer disturbances is essential. The Elephants in the study area are still using a compact block of forest and hence elephant-human conflict can be managed easily. As the density of elephants increase in the study area, elephant groups at the periphery of this range will be forced to use areas outside the Park boundaries. It is these areas which have a very high level of disturbance where elephant-human conflict would be severe. Therefore, it is necessary to plan an elephant habitat management plan for this elephant range that takes into account all the above factors and addresses the issue of habitat degradation outside the study area in the adjacent Siwalik and Dehradun Forest divisions. A positive step in this direction is the recent moves to resettle *Gujjars* outside the Park. The impact of this reduction in disturbance on elephant ranging will be interesting to study in the future.

ACKNOWLEDGEMENTS

We thank the Officers of the Uttarakhand Forest Department, the Additional Inspector General of Forests (Wildlife), Ministry of Environment and Forests, Government of India and Director, Project Elephant, Government of India who granted the permissions for this study. We wish to thank the faculty and staff at the Wildlife Institute of India and the University of Arizona who helped us during analysis and writing the first authors' Ph.D. which led to this manuscript. The United States Fish and Wildlife Service funded this project and we particularly thank Dave Ferguson and Fred Bagley for all the encouragement and support rendered to carry out this research.

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PRESENT STATUS OF FLORISTIC DIVERSITY OF MOTHRONWALA SWAMP FOREST OF DOON VALLEY [1]

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Doon Valley has many freshwater swamps, due to its unique topography and peculiar situation in the foothills of the Himalaya. One such swamp is Mothronwala Freshwater Swamp, where the present study was carried out. It occurs as a compact area between 30° 15' N and 78° 2' E, with an average altitude of 600 m above msl. In this paper, we have attempted to study the structure of the vegetation of Mothronwala Swamp. Dakshini (1970, 1974) had reported 356 species of flowering plants with 261 genera and 71 families from this Swamp. The Mothronwala Swamp Forest was resurveyed after four decades and a number of changes were recorded in its vegetation. There is a decline in number of species; only 278 species of flowering plants in 218 genera and 71 families were recorded during the present study (2002-2003).

Key words: Doon Valley, floristic diversity, Mothronwala, swamp

INTRODUCTION

Freshwater swamps are locally known as *oogals* and are dominated by unique plant species. They often have standing water for most of the growing seasons (Mitsch and Gosselink 1986). Swamps and marshes are considered as the source of mosquitoes that cause malaria. However, swamps are known to absorb toxic chemicals and even clean up polluted water as in natural treatment plants (NTPs). Swamp forests are an integral part of wetland ecosystems, serving as habitats, spawning areas and sources of food for many organisms (Brown *et al.* 1979; Wharton and Brinson 1979). Indian freshwater swamps are found along the sub-montane tract of the Himalaya. These generally occur along the banks of terai streams in the outer range of the Himalaya up to an elevation of 2,580 m.

References to the Mothronwala Fresh Water Swamp are found in the flora of the upper Gangetic plain, and the adjacent Siwalik and sub-Himalayan Tracts by Duthie (1903-1922) and 'Herbaceous flora of Doon' by Babu (1977). The flora of Chakrata, Dehradun and Saharanpur divisions has been studied by Kanjilal (1901). In Doon Valley, the freshwater swamps occur as localised habitats that have come up as a result of special topography, where water oozes out in perennial streams and sub-soil water maintains a constant level throughout the year above the surface of the soil (Dakshini 1968). This results in a unique wetland ecosystem with vegetation entirely different from the surrounding area. However, the urban expansion of the valley has led to continuous encroachment of forestland, and swamps are no exception. Presently, only a few small and scattered patches of swamps are left between the base of the outer hills of the Himalaya in the north and the Siwalik Hills in the south. Among these, Mothronwala is the most accessible nearest and among the most important swamp forests of Doon valley.

Mothronwala Freshwater Swamp Forest used to possess a peculiar floristic diversity due to its topographic and edaphic variation. The forest of this region has depleted during the last four decades due to its exploitation for fuel, food, fodder and timber. The Mothronwala Swamp Forest has experienced very high pressure, and a lot of changes have been recorded in the vegetation of the Swamp.

Som and Aswal (1974) have studied the vegetation of Mothronwala Freshwater Swamp, apart from the detailed study on the vegetation of the swamp conducted by Dakshini (1960a, b, 1965, 1968, 1970, 1974). The present paper attempts to re-explore the floristic diversity of Mothronwala Swamp and compare it with Dakshini (1970 and 1974).

MATERIAL AND METHODS

Doon Valley is located between 29° 30'-30° 32' N and 77° 39'-78° 18' E in Uttarakhand, India. The present study was conducted during 2002-2003 in the Mothronwala Freshwater Swamp Forest (Fig. 1). Care was taken to re-survey the areas surveyed by Dakshini (1960). The usual methods of collection, preservation and maintenance of specimens in herbarium were followed (Jain and Rao 1977). A total of 42 trips was made for collection in different seasons. During the field study, specimens of plants with flower and fruit were recorded. Collections of plant species were made throughout the year. The field data namely the habit, habitat, flower colour and vernacular name of each taxon were recorded.

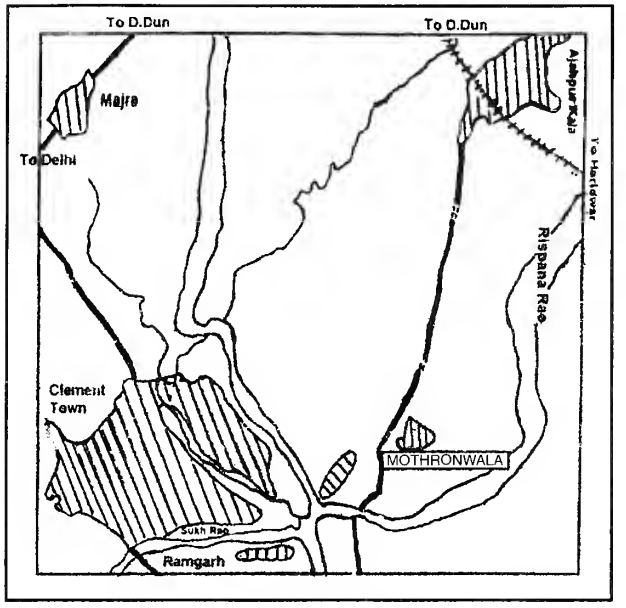

Fig. 1: Location map of study area

After collection, the specimens were processed, preserved and mounted on herbarium sheets. The herbarium sheets were identified in the BSD Herbarium and deposited in the Herbarium of the Ecology Research Laboratory, Botany Department, D.A.V. (P.G.) College, Dehradun. The descriptions of plants in the available literature were studied (Gaur 1999; Babu 1977). All plant species are arranged according to Bentham and Hooker's system of classification.

RESULTS AND DISCUSSION

During the study, 278 species of angiosperms in 218 genera and 71 families were collected from the study site. Out of 278 species, 219 species in 173 genera are Dicotyledons, and 59 species in 45 genera are Monocotyledons. The floristic diversity of Mothronwala fresh water Swamp Forest during the study period 2002-2003 is presented in (Table 1).

Dakshini (1970, 1974) reported 356 species of flowering plants belonging to 261 genera and 71 families. Sixty families represented dicots of 201 genera and 276 species. A total of 11 families of monocots had 60 genera and 80 species (Table 2).

Fabaceae and Asteraceae are the dominant families of dicots. Family Fabaceae includes the largest number of species (30) and genera (20); Asteraceae includes (26) species and (21) genera. Dakshini (1960a, 1974) also reported Fabaceae and Asteraceae as the dominant families of dicots. Comparison of dominant genera and species of various families of dicots in Mothronwala Freshwater Swamp is shown in (Fig. 2). Among the monocots, Family Poaceae is dominated with 28 genera and 34 species followed by Cyperceae with 4 genera and 12 Species (Fig. 3).

Dakshini (1965) reported 38 tree, 52 shrub, 42 climber and 235 herb species. The present study indicates that the forest of this region has depleted at a very fast rate during the last four decades. Presently, the vegetation structure of the swamp is 25 tree, 34 shrub, 25 climber and 194 herb species (Table 3). A clear decline of 13 tree, 18 shrub, 17 climber, and 41 herb species is evident from the vegetation structure.

The dominant families of the present study are Fabaceae, Asteraceae, Poaceae, Cyperaceae, Scrophulariaceae and Convolvulaceae. A comparison of a number of taxa recorded by Dakshini and in the present study are presented in Table 4. Fourteen new families which includes 4 species of trees and 11 species of herbs, have been recorded from the Mothronwala Freshwater Swamp (Table 5).

Table 6 indicates the plant species of Mothronwala Swamp reported by Dakshini (1970, 1974), but absent in the present area. A very common tree species of Doon valley swamps

Table 1: Floristic diversity of Mothronwala Freshwater Swamp during the study period (2002-2003)

Groups	Family	Genera	Species
Dicotyledons	60	173	219
Monocotyledons	11	45	59
Total	71	218	278

Table 2: Comparison of families, genera and species of angiosperms of Mothronwala Freshwater Swamp

Groups	Families		Genera		Species	
	D	P	D	P	D	P
Dicotyledons	60	60	201	173	276	219
Monocotyledons	11	11	60	45	80	59
Total	71	71	261	218	356	278

D = Dakshini; P = Present work

Table 3: Comparison of the vegetation structure of the Swamp

Life-forms	Dakshini	Present work
Herbs	235	194
Shrubs	52	34
Climbers	42	25
Trees	38	25

Table 4: Comparison of number of genera and species reported in the present study and by Family in Dakshini

Family	Dakshini		Present work		Family	Dakshini		Present work	
	Genera	Species	Genera	Species		Genera	Species	Genera	Species
Ranunculaceae	2	2	2	4	Primulaceae	2	2	2	2
Papaveraceae	-	-	1	1	Myrsinaceae	1	1	1	1
Menispermaceae	3	3	1	1	Ebenaceae	1	1	-	-
Fumariaceae	-	-	1	1	Oleaceae	1	1	1	1
Brassicaceae	2	2	4	4	Apocynaceae	6	6	3	3
Capparaceae	1	1	1	1	Asclepiadaceae	1	1	1	1
Cleomaceae	-	-	1	1	Boraginaceae	4	4	3	5
Violaceae	1	1	1	1	Ehertiaceae	1	2	1	1
Bixaceae	1	1	1	1	Convolvulaceae	3	7	2	10
Polygalaceae	1	1	-	-	Solanaceae	3	5	5	7
Caryophyllaceae	-	-	2	2	Scrophulariaceae	7	11	6	10
Dipterocarpaceae	1	1	-	-	Pedaliaceae	1	1	1	1
Malvaceae	5	7	6	8	Acanthaceae	10	13	8	9
Bombacaceae	1	1	1	1	Verbenaceae	7	10	8	9
Sterculiaceae	3	3	2	2	Lamiaceae	10	13	7	8
Tiliaceae	3	4	3	4	Nyctaginaceae	1	1	1	1
Linaceae	1	1	1	1	Amaranthaceae	5	6	5	5
Malpighiaceae	1	1	-	-	Chenopodiaceae	-	-	1	1
Geraniaceae	1	1	1	1	Polygonaceae	1	4	2	4
Oxalidaceae	1	1	1	2	Piperaceae	-	-	1	1
Rutaceae	5	6	4	4	Lauraceae	3	5	1	1
Burseraceae	1	1	-	-	Proteaceae	-	-	1	1
Meliaceae	1	1	2	2	Elagenaceae	1	1	-	-
Celastraceae	1	1	-	-	Euphorbiaceae	7	10	5	5
Rhamnaceae	4	4	2	2	Urticaceae	8	17	4	4
Vitaceae	2	2	1	1	Moraceae	-	-	2	3
Leeaceae	1	2	1	1	Ulmaceae	-	-	1	1
Sapindaceae	1	1	-	-	Fagaceae	-	-	1	1
Sabiaceae	1	1	-	-	Salicaceae	1	1	-	-
Anacardiaceae	1	1	1	1	Orchidaceae	4	5	-	-
Fabaceae	25	51	20	30	Musaceae	-	-	1	1
Rosaceae	3	3	4	4	Zingiberaceae	6	7	2	2
Myrtaceae	2	2	1	1	Cannaceae	-	-	1	1
Melastomataceae	1	1	-	-	Hypoxidaceae	1	1	-	-
Lythraceae	3	4	-	-	Amaryllidaceae	-	-	2	2
Passifloraceae	1	1	1	2	Dioscoreaceae	1	3	1	1
Cucurbitaceae	3	3	3	5	Liliaceae	4	4	2	2
Aizoaceae	-	-	1	1	Commelinaceae	3	5	2	2
Apiaceae	1	1	1	1	Juncaceae	1	1	-	-
Araliaceae	1	1	-	-	Arecaceae	1	1	1	1
Cornaceae	-	-	1	1	Araceae	3	3	1	1
Rubiaceae	7	8	4	4	Cyperaceae	5	13	4	12
Asteraceae	23	26	21	26	Poaceae	30	37	28	34
Plumbaginaceae	1	1	1	1	Total	261	356	218	278

Bischofia javanica, reported by Kanjilal (1901) and Dakshini (1970, 1974), was not recorded during the present study. Dakshini (1970, 1974) reported 356 species of angiosperms, out of which 238 species were not found during the present study. Similarly, 135 new plant species reported during the present study, were not reported by Dakshini (1970, 1974) (Table 7).

CONCLUSION

Local extinction of 211 plant species and immigration of 135 tolerant, opportunistic species in the last three decades can be due to the fact that Mothronwala Freshwater Swamp has witnessed a continued increase in human population due to various reasons; namely its proximity to the expanding

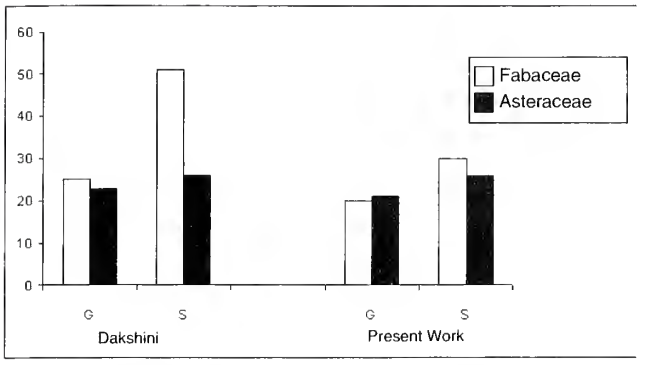

Fig. 2: Comparison of dominant dicot genera (G) and species (S) of Mothronwala Freshwater Swamp

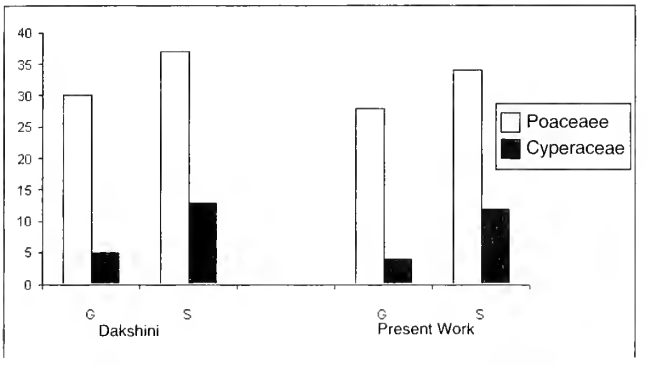

Fig. 3: Comparison of dominant monocot genera (G) and species (S) of Mothronwala Freshwater Swamp

Dehradun city, fear of swamp as a disease source, drainage of swampy water for drinking water requirements, farming on encroached forest lands, urbanization on its periphery and unmindful destruction of forest wealth by peripheral villagers for various wood and non-wood products.

Table 5: New families reported from Mothronwala Swamp

Family	Plant species
Cannaceae	*Canna indica* Linn.
Ulmaceae	*Celtis australis* Linn.
Chenopodiaceae	*Chenopodium album* Linn.
Cleomaceae	*Cleome viscosa* Linn.
Cornaceae	*Cornus oblonga* Wallich.
Amaryllidaceae	*Crinum defixum* Ker-Gawler
Fumariaceae	*Fumaria parviflora* Lamk.
Porteaceae	*Grevillea robusta* A. Cunn.
Aizoaceae	*Mollugo pentaphylla* Linn.
Musaceae	*Musa balbisiasna* Colla
Piperaceae	*Peperomia pellucida* (Linn.) HBK
Fagaceae	*Quercus leucotrichophora* A. Camus
Caryophyllaceae	*Silene conoidea* Linn.
	Stellaria media (Linn.) Vill.
Amaryllidaceae	*Zephyranthes grandiflora* Lindley

ACKNOWLEDGEMENTS

We are grateful to Dr. Sumer Chand, Scientist Botany Branch, FRI and Dr. P.C. Pant of BSI (NC) Dehradun for assisting in identification and to reviewing the manuscript.

Table 6: Plants reported by Dakshini but absent in the present study

Plant spp.	Family	Plant spp.	Family
Cocculus laurifolius DC.	Menispermaceae	*Acer oblongum* Wall. ex DC.	Sapindaceae
Tinospora glabra (Burm.f.) Merill	Menispermaceae	*Sabia paniculata* Edgew ex Hook.f. &Thoms.	Sabiaceae
Polygala crotalarioides Buch.-Ham.	Polygalaceae	*Lannea coromandelica* (Houtt.) Merrill.	Anacardiaceae
Shorea robusta Gaertn.	Dipterocarpaceae	*Abrus fruticulosus* Wall ex Wight & Arn.	Fabaceae
Abelomoschus crinitus Wall.	Malvaceae	*Acacia farnesiana* Willd.	Fabaceae
Sida acuta Burm.f.	Malvaceae	*Aeschynomene indica* Linn.	Fabaceae
Salmalia malabarica (DC.) Schott & Endl.	Bombacaceae	*Albizzia stipulata* Boiv. var. *smithana* Prain	Fabaceae
Melochia corchorifolia Linn.	Sterculiaceae	*Alysicarpus bupleurifolius* (Linn.) DC.	Fabaceae
Sterculia villosa Roxb.	Sterculiaceae	*Alysicarpus glumaceus* (Vahl.) DC.	Fabaceae
Grewia disperma Rottl. ex Spreng.	Tiliaceae	*Alysicarpus vaginalis* (Linn.) DC.	Fabaceae
Grewia polygama Roxb.	Tiliaceae	*Butea monosperma* (Lamk.) Taub	Fabaceae
Hiptage bengalensis (Linn.) Kurz	Malpighiaceae	*Butea parviflora* Roxb. ex DC.	Fabaceae
Acronychia pedunculata (Linn.) Miq.	Rutaceae	*Cassia leschenaultiana* DC.	Fabaceae
Murraya paniculata (Linn.) Jack.	Rutaceae	*Cassia occidentalis* Linn.	Fabaceae
Garuga pinnata Roxb.	Burseraceae	*Crotalaria albida* Heyne ex Roth.	Fabaceae
Celastrus paniculata Willd.	Celastraceae	*Crotalaria calycina* Schrank.	Fabaceae
Rhamnus virgata Roxb.	Rhamnaceae	*Crotalaria ferruginea* R. Grah. ex Benth.	Fabaceae
Ventilago denticulata Willd.	Rhamnaceae	*Crotalaria sericea* Retz.	Fabaceae
Vitis parviflora Roxb.	Vitaceae	*Crotalaria sessiliflora* Linn.	Fabaceae
Leea alata Edgeworth	Leeaceae	*Crotalaria prostrata* Rottl. ex Willd.	Fabaceae
Leea edgeworthii Santapau	Leeaceae	*Desmodium motorium* (Houtt.) Merrill	Fabaceae

Table 6: Plants reported by Dakshini but absent in the present study (*contd.*)

Plant spp	Family	Plant spp	Family
Desmodium retusum (D.Don) Swert.	Fabaceae	*Cryptolepis buchananii* Roem. & Schult.	Asclepiadaceae
Desmodium triquetrum (Linn.) DC.	Fabaceae	*Bothriospermum tenellum* Fisch. & Mey.	Boraginaceae
Indigofera atropurpurea Buch.-Ham. ex Roxb.	Fabaceae	*Cordia dichotoma* Forst.f.	Boraginaceae
Indigofera glandulosa Willd.	Fabaceae	*Cynoglossum meeboldii* Brand.	Boraginaceae
Millettia auriculata Baker	Fabaceae	*Argyreia thomsoni* (Clarke) Craib.	Convolvulaceae
Moghania bracteata (Roxb.) Linn.	Fabaceae	*Ipomoea dichroa* (Roem & Schult) Choisy	Convolvulaceae
Moghania prostrata (Roxb.f.) Mukerjee	Fabaceae	*Ipomoea thomsoni* (Clarke) Craib.	Convolvulaceae
Moghania semialata (Roxb.) Mukerjee	Fabaceae	*Rivea ornata* Choisy.	Convolvulaceae
Mucuna prurita Hook.	Fabaceae	*Cestrum nocturnum* Linn.	Solanaceae
igna umbellata (Thunb.) Ohwi & Ohashi	Fabaceae	*Solanum indicum* Linn.	Solanaceae
Pueraria phaseoloidea Benth.	Fabaceae	*Centranthera nepalensis* D. Don	Scrophulariaceae
Rhynchosia rothii Benth. ex Altchison	Fabaceae	*Lindernia anagalis* (N.L. Burm.) Pennell	Scrophulariaceae
Sesbania sesban (Linn.) Merrill	Fabaceae	*Lindernia ciliata* (Colsmann) Penell	Scrophulariaceae
Tephrosia candida DC.	Fabaceae	*Lindernia cordifolia* (Colsmann) Merill	Scrophulariaceae
Uraria picta Desv.	Fabaceae	*Lindernia hookeri* (Clarke) Wettstt.	Scrophulariaceae
Uraria rufescens (DC.) Schindl.	Fabaceae	*Limnophila rugosa* (Roth) Merrill	Scrophulariaceae
Vigna capensis (L.) Walp.	Fabaceae	*Mimulus strictus* Benth.	Scrophulariaceae
Zorina gibbosa Span.	Fabaceae	*Torenia cordifolia* Roxb.	Scrophulariaceae
Syzygium cerasoides (Roxb.) Raizada	Myrtaceae	*Veronica anagallis aquatica* Linn.	Scrophulariaceae
Sonerilla tenera Royle	Melastomataceae	*Sesamum orientale* Linn.	Pedaliaceae
Ammannia baccifera Linn.	Lythraceae	*Hygrophila polysperma* (Roxb.) T. Anders.	Acanthaceae
Rotala mexicana Cham. & Schlect	Lythraceae	*Hygrophila salicifolia* (Vahl.) Nees	Acanthaceae
Rotala rotundifolia Koehne.	Lythraceae	*Hemigraphis latebrosa* Nees	Acanthaceae
Woodfordia fruticosa (Linn.) Kurz.	Lythraceae	*Rungia pectinata* (Linn.) Nees	Acanthaceae
Cucumis melo Naud.	Cucurbitaceae	*Clerodendrum indicum* (Linn.) Kuntze	Verbenaceae
Mukia maderaspatana (Linn.)	Cucurbitaceae	*Clerodendrum serratum* (Linn.) Moon	Verbenaceae
Schefflera venulosa (Wt. & Arn.) Harms	Araliaceae	*Lantana crenulata* Otto & Dietr.	Verbenaceae
Borreria articularis (Linn.f.) F.N. Williams	Rubiaceae	*Premna herbacea* (Roxb.)	Verbenaceae
Borreria ocymoides DC.	Rubiaceae	*Acrophalus indicus* (Burm.)	Lamiaceae
Knoxia corymbosa Willd.	Rubiaceae	*Ajuga bracteosa* Wall. ex Benth.	Lamiaceae
Oldenlandia corymbosa Linn.	Rubiaceae	*Colebrookia oppositifolia* Smith	Lamiaceae
Pavetta tomentosa Roxb. ex Rees.	Rubiaceae	*Leucas lanata* Benth.	Lamiaceae
Rubia cordifolia Linn.	Rubiaceae	*Leucas nutans* Spreng.	Lamiaceae
Adenostemma lavenia (Linn.) O. Kuntze	Asteraceae	*Mosla dianthera* (Buch.-Ham. ex Roxb.) Maxim.	Lamiaceae
Adenostemma viscosum J.R. & G. Forster	Asteraceae	*Nepeta graciliflora* Benth.	Lamiaceae
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	*Orthosiphon rubicundus* Benth.	Lamiaceae
Blumea lanceolaria (Roxb.) Druce	Asteraceae	*Plectranthus japonicus* (Burm.f.) Koidz.	Lamiaceae
Cirsium wallichii DC.	Asteraceae	*Teucrium stoloniferum* Roxb.	Lamiaceae
Conyza japonica Lees.	Asteraceae	*Achyranthus bidentata* Blume.	Amaranthaceae
Crepis acaulis (DC.) Hook.f.	Asteraceae	*Amaranthus spinosus* Linn.	Amaranthaceae
Cyathocline purpurea (D. Don) Kuntze.	Asteraceae	*Celosia argentea* Linn.	Amaranthaceae
Echinops cornigerus DC.	Asteraceae	*Polygonum stagninum* Buch.-Ham.	Polygonaceae
Eclipta prostrata (Linn.) Linn.	Asteraceae	ex Meisn	
Gnaphalium indicum Linn.	Asteraceae	*Machilus gamblei* King ex Hook.f.	Lauraceae
Inula cappa (Buch.-Ham. ex D. Don) DC.	Asteraceae	*Persea gamblei* (King ex Hook.f.) Kosterm.	Lauraceae
Tricholepis stictophylla Clarke	Asteraceae	*Persea odoratissima* (Nees) Kostermans	Lauraceae
Vicoa indica (Linn.) DC.	Asteraceae	*Phoebe lanceolata* Nees	Lauraceae
Wedelia wallichii Less	Asteraceae	*Elaeganus conferta* Roxb.	Elagenaceae
Xanthium strumarium Linn.	Asteraceae	*Antidesma diandrum* Roth.	Euphorbiaceae
Youngia japonica (Linn.) DC.	Asteraceae	*Baliospermum montanum* (Willd.) Muell-Arg	Euphorbiaceae
Diospyros montana Roxb.	Ebenaceae	*Bischofia javanica* Blume	Euphorbiaceae
Carissa opaca Stapf. ex Haines.	Apocynaceae	*Euphorbia hypercifolia* Linn.	Euphorbiaceae
Rauwolfia serpentina Benth. ex Kuntze	Apocynaceae	*Euphorbia dracunculoides* Lam.	Euphorbiaceae
Tabernaemontana divaricata (Linn.) R.Br.	Apocynaceae	*Phyllanthus virgatus* J.G. Forst	Euphorbiaceae
ex & Schult.		*Boehmeria platyphylla* D. Don.	Urticaceae
Trachelospermum lucidum (D. Don) K. Schum.	Apocynaceae	*Cudrania javanensis* Trecul.	Urticaceae

Table 6: Plants reported by Dakshini but absent in the present study (*contd.*)

Plant spp	Family	Plant spp	Family
Elatostema cuneatum Wight	Urticaceae	*Remusatia vivipara* Schott	Araceae
Ficus gibbosa Blume var. *cuspidifera* Miq.	Urticaceae	*Cyperus pilosus* Vahl	Cyperaceae
Ficus auriculata Lour.	Urticaceae	*Carex fedia* Nees	Cyperaceae
Ficus arnottiana Miq.	Urticaceae	*Cyperus kyllingia* Endl.	Cyperaceae
Ficus hederacea Roxb.	Urticaceae	*Scleria levis* Retz.	Cyperaceae
Ficus hispida Linn.f.	Urticaceae	*Scleria tessellata* Willd.	Cyperaceae
Ficus racemosa Linn.	Urticaceae	*Scirpus erectus* Poir.	Cyperaceae
Ficus rumphii Blume	Urticaceae	*Anthraxon lancifolius* (Trin.) Hochst.	Poaceae
Ficus semicordata Buch.-Ham.	Urticaceae	*Anthraxon prionodes* (Steud.) Dandy	Poaceae
Salix tetrasperma Roxb.	Salicaceae	*Arundinella nepalensis* Trin.	Poaceae
Eulophia flava (Lindl. ex Royle) Hook.f.	Orchidaceae	*Arundo donax* Linn.	Poaceae
Zeuxine strateumataica (Linn.) Schlechter	Orchidaceae	*Chionachne koinigii* (Spreng.) Thw.	Poaceae
Habenaria commelinifolia Wall.	Orchidaceae	*Chrysopogon fulvus* (Spreng.) Chiovenda.	Poaceae
Habenaria diphylla Dalz.	Orchidaceae	*Cyrtococcum patens* (Linn.) A. Camus	Poaceae
Peristylus lawii Wight	Orchidaceae	*Digitaria adscendens* (Kunth) Henrad	Poaceae
Alpinia bracteata Roxb.	Zingiberaceae	*Eragrostis gangetica* (Roxb.) Steud.	Poaceae
Curcuma longa Linn.	Zingiberaceae	*Elusine coracana* (Linn.) Gaertn.	Poaceae
Costus speciosus Smith	Zingiberaceae	*Eragrostis tenella* (Linn.) P. Beauv. ex Roem.et Schult.	Poaceae
Curcuma angustifolia Roxb.	Zingiberaceae		
Hedychium coronarium Koen. ex Retz.	Zingiberaceae	*Hemarthria compressa* (Linn. f.) R.Br.	Poaceae
Curculigo orchioides Gaertn.	Hypoxidaceae	*Narenga porphyrocoma* (Hance) Bor.	Poaceae
Dioscorea belophylla Voiget.	Dioscoreaceae	*Pennisetum orientale* L.C. Rich.	Poaceae
Dioscorea pentaphylla Linn.	Dioscoreaceae	*Phragmites communis* Trin. var. *communis* Bor.	Poaceae
Gagea reticulata Schultes f.	Liliaceae		
Gloriosa superba Linn.	Liliaceae	*Polypogon monspeliensis* (Linn.) Defontaines	Poaceae
Smilax glaucophylla Klotzsch.	Liliaceae		
Commelina paludosa Blume	Commelinaceae	*Pseudosorghum fasciculare* (Roxb.)	Poaceae
Floscopa scandens Lour.	Commelinaceae	*Rottboellia exaltata* Linn.f.	Poaceae
Murdania scapiflorum (Roxb.) Royle	Commelinaceae	*Setaria plicata* (Lamk.) T. Cooke	Poaceae
Juncus bufonius Linn.	Juncaceae	*Sorghum halepense* (Linn.) Pers.	Poaceae
Arisaema tortuosum (Wallich) Schott	Araceae	*Themeda arundinacea* (Roxb.) Ridley	Poaceae

Table 7: New plant species in the study area

Plant species	Family	Plant species	Family
Ranunculus arvensis Linn.	Ranunculaceae	*Mangifera indica* Linn.	Anacardiaceae
Ranunculus muricata Linn.	Ranunculaceae	*Albizia mollis* Boivin.	Fabaceae
Argemone mexicana Linn.	Papaveraceae	*Alysicarpus rugosus* (Willd.) DC.	Fabaceae
Fumaria parviflora Lam.	Fumariaceae	*Bauhina variegata* Linn.	Fabaceae
Brassica juncea (L.) Czern. &. Coss.	Brassicaceae	*Casia obtusifolia* Linn.	Fabaceae
Capsella bursa pestoris (Linn.) Medikus	Brassicaceae	*Crotolaria spectabilis* Lamk.	Fabaceae
Cleome viscosa Linn.	Cleomaceae	*Desmodium gyrans* (Linn.f.) DC.	Fabaceae
Silene conoidea Linn.	Caryophyllaceae	*Fleminigia strobilifera* (Linn.) R.Br.	Fabaceae
Stellaria media (Linn.) Villars	Caryophyllaceae	*Lespideza juncea* Pers.	Fabaceae
Malvastrum coromandelicum (Linn.) Gracke	Malvaceae	*Melilotus indica* (Linn.) Allioni	Fabaceae
Sida cordifolia Linn.	Malvaceae	*Millettia externsa* (Benth.) Baker	Fabaceae
Sida rhombifolia Linn. emend. Mast.	Malvaceae	*Mimosa pudica* Linn.	Fabaceae
Bombax ceiba Linn.	Bombacaceae	*Phaseolus avernus* Roxb.	Fabaceae
Pterospermum acerifolium (Linn.) Willd.	Sterculiaceae	*Phaseolus mungo* Linn.	Fabaceae
Corchorus olitorius Linn.	Tiliaceae	*Vicia sativa* Linn.	Fabaceae
Grewia optiva J.R. Drummond ex Burret	Tiliaceae	*Vigna unguiculata* (Linn.) Walp.	Fabaceae
Oxalis debilis Humb.	Oxalidaceae	*Rosa macrophylla* Lindley.	Rosaceae
Melia azadirach Linn.	Meliaceae	*Passiflora suberosa* Linn.	Passifloraceae
Leea aspera Edgew.	Leeaceae	*Cucumis sativus* Linn.	Cucurbitaceae

Table 7: New plant species in the study area (*contd.*)

Plant species	Family	Plant species	Family
Momordica charantia Linn.	Cucurbitaceae	*Veronica salina* Schur.	Scrophulariaceae
Trichosanthes cordata Roxb.	Cucurbitaceae	*Sesamum orientale* Linn.	Pedaliaceae
Trichosanthes cucumeria Linn.	Cucurbitaceae	*Rungia parviflora* (Retz.) Nees	Acanthaceae
Mollugo pentaphylla Linn.	Aizoaceae	*Rungia repens* (Linn.) Nees	Acanthaceae
Cornus oblonga Wallich.	Cornaceae	*Clerodendron siphoranthus* R.Br.	Verbenaceae
Galium asperifolium Wallich.	Rubiaceae	*Duranta repens* Linn.	Verbenaceae
Oldenlandia cocinea (Royle) Hook.f.	Rubiaceae	*Vitex negundo* Linn.	Verbenaceae
Randia tetraspermea (Roxb.) Benth. & Hook.f.	Rubiaceae	*Leucas cephalata* (Roth.) Spreng.	Lamiaceae
Ageratum houstonianum Mill.	Asteraceae	*Mentha piperita* Linn.	Lamiaceae
Artemisia parviflora Buch.-Ham. ex D. Don	Asteraceae	*Perilla frutescens* (Linn.) Britt.	Lamiaceae
Artemisia rouxburghiana Wallich ex Besser	Asteraceae	*Plectranthus coetsa* Buch.-Ham.ex D.Don	Lamiaceae
Cichorium intybbus Linn.	Asteraceae	*Salvia plebbia* R. Br.	Lamiaceae
Cnicus arvensis (Linn.) Hoffm.	Asteraceae	*Amaranthus viridis* Linn.	Amaranthaceae
Cnicus wallichii (DC.) Hook.f.	Asteraceae	*Chenopodium album* Linn.	Chenopodiaceae
Dicrocephala latifolia DC.	Asteraceae	*Rumex dentatus* Linn.	Polygonaceae
Eclipta alba (Linn.) Hassk.	Asteraceae	*Peperomia pellucida* (Linn.) Kunth	Piperaceae
Enhydra fluctuans Lour.	Asteraceae	*Listea monopetala* (Roxb.) Pers.	Lauraceae
Eupatorium adenophorum Sprengel.	Asteraceae	*Grevillea robusta* A. Cunn	Proteaceae
Galinsoga ciliata (Rafinesque-Schmatz)	Asteraceae	*Ricinus communis* Linn.	Euphorbiaceae
Lauanea nudicaulis (Linn.) Hook.f.	Asteraceae	*Celtis australis* Linn.	Ulmaceae
Saussurea heteromalla (D. Don) Hand-Mazz	Asteraceae	*Quercus leucotrichophora* A. Camus	Fagaceae
Synedrella vialis (Lees) A. Gray	Asteraceae	*Musa balbisiasna* Colla	Musaceae
Taraxacum officinale Weber	Asteraceae	*Canna indica* Linn.	Cannaceeae
Vernonia anthelmintica (Linn.) Willd.	Asteraceae	*Crinum defixum* Ker-Gawler	Amaryllidaceae
Xanthium indicum Koenig.	Asteraceae	*Zephyranthes grandiflora* Lindley	Amaryllidaceae
Carissa congesta Wight	Apocynaceae	*Smilax zeylanica* Linn.	Liliaceae
Marsdenia roylei Wight	Asclepiadaceae	*Cyperus brevifolius* (Rottb.) Hassk	Cyperaceae
Cynoglossum lanceolotum Forsk.	Boraginaceae	*Cyperus compressus* Linn.	Cyperaceae
Cynoglossum wallichii G. Don	Boraginaceae	*Carex wallichiana* Presc.	Cyperaceae
Cynoglossum zeylanicum (Vahl. ex Hornem).	Boraginaceae	*Fimbristylis bisumbellata* (Forsk.) Bub.	Cyperaceae
		Sciprus supinus Linn.	Cyperaceae
Evolvulus alsinodes (Linn.) Linn.	Convolvulaceae	*Avena sativa* Linn.	Poaceae
Evolvulus nummularius (Linn.) Linn.	Convolvulaceae	*Bambusa arundinacea* Willd.	Poaceae
Ipomoea carnea Jacquin Enum.	Convolvulaceae	*Chrysopogon aculatus* (Retz.) Trin.	Poaceae
Ipomoea cairica (Linn.) Sweet	Convolvulaceae	*Chrysopogon montanus* (Retz.)Trin.	Poaceae
Ipomoea quamoclit Linn.	Convolvulaceae	*Cynodon dactylon* (Linn.) Pers.	Poaceae
Ipomoea nil (Linn.) Roth	Convolvulaceae	*Cyrtococcum accrescens* (Trin.) Stapf.	Poaceae
Ipomoea purpurea (Linn.) Roth	Convolvulaceae	*Digitaria biformis* Willd.	Poaceae
Datura alba Nees	Solanaceae	*Ergrastosis japonica* (Thunb) Trinius	Poaceae
Nicotiana plumbaginifolia Viviani	Solanaceae	*Paspalum distichum* Linn.	Poaceae
Petunia violaceae Lindl.	Solanaceae	*Paspalidum flavidum* (Retz.) A. Camus	Poaceae
Solanum xanthocarpum Schard. & Wendl.	Solanaceae	*Phragmetis karka* (Retz.)Trinius ex Steudel.	Poaceae
Bacopa procumbens (Miller) Greenman	Scrophulariaceae	*Poa annua* Linn.	Poaceae
Lindenbergia indica (Linn.) O. Kuntze	Scrophulariaceae	*Polypogon fugax* Nees ex Steud.	Poaceae
Mazus delavayi Bonati.	Scrophulariaceae	*Setaria tomentosa* (Roxb.) Kunth.	Poaceae
Mazus pumilus (Burm.f.) Steen.	Scrophulariaceae	*Sporobolus diander* (Retz.) P. Beauv.	Poaceae
Scoparia dulcis Linn.	Scrophulariaceae	*Sporobolus tennuis* (Schrank) O. Kuntze	Poaceae
Veronica agrestis Linn.	Scrophulariaceae	*Sorghum nitidum* (Vahl.) Pers.	Poaceae
Veronica persica Poiret	Scrophulariaceae	*Vetiveria zizanioides* (Linn.) Nash.	Poaceae

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ESTIMATION OF PREY BASE AND ITS IMPLICATIONS IN KUNO WILDLIFE SANCTUARY

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The Asiatic Lion *Panthera leo persica* is restricted to the Gir National Park and Sanctuary in India, which is the only site holding the last surviving wild population of Asiatic Lion in the world. Kuno Wildlife Sanctuary (WLS) in northwest Madhya Pradesh was selected as the site to establish a second home for the Asiatic Lion. Twenty-four villages were rehabilitated outside the Sanctuary to create a large forest habitat free from human disturbance for the Lions. To assess wild prey availability for the Lions in the Sanctuary, distance sampling method was used to collect and analyse data from roads traversed as transects. Cattle population was estimated using direct head counts at yarding sites. The study was carried out in 2004. The estimated combined density of all the major prey excluding Common Langur and cattle in the Sanctuary was 12.11 animals/sq. km. It was found that the total available prey base including feral cattle and wild ungulates was 1993 kg/sq. km, which is still less than the wild prey biomass of 2784.9 kg/sq. km reported from Gir. While this prey base can support a small reintroduced population of 6-10 Lions, it is recommended that efforts to develop a sufficient wild prey base be given the highest management priority.

Key words: Asiatic Lion, extinction, prey base, distance sampling, prey biomass, habitat recovery.

INTRODUCTION

The only free-ranging population of Asiatic Lions *Panthera leo persica* survive in Gir National Park and Sanctuary (Gir forest) of the western Indian state of Gujarat. In the past, their population declined to its lowest number in 1893 when only 18 individuals remained (Saberwal *et al.* 1994; Divyabhanusinh 2005). Following conservation efforts, the species has made a remarkable recovery (Joslin 1973; Berwick 1974; Chellam 1993; Jhala *et al.* 1999; Divyabhanusinh 2005). This isolated, small and single population of Asiatic Lion in Gir faces a variety of extinction threats (Soule 1987) and reintroduction is one of the measures advocated to ensure its long term survival (Sale 1986; IUCN/SSC-RSG).

In 1993, during a workshop on Population and Habitat Viability Analysis at Vadodara (now Baroda), a list of protected areas that could potentially serve as an alternate home for some lions was drafted in consultation with the forest departments of Gujarat, Uttar Pradesh, Madhya Pradesh, Rajasthan and Haryana. After an extensive survey of several potential sites, three locations were short-listed as possible re-introduction sites for this population. These were Darrah and Jawaharsagar Wildlife Sanctuaries (WLS) and Sitamata WLS in Rajasthan, and Kuno WLS in Madhya Pradesh. After an assessment of these sites, Kuno WLS was selected as the most suitable site for translocation of Lions from the Gir forest to establish a second free-ranging population in India (Chellam *et al.* 1995). After its selection as the site for translocation of the Asiatic Lions, one of the first tasks undertaken by the Kuno WLS management was the rehabilitation of the twenty four villages situated within the Sanctuary. This was considered necessary to create a large inviolate core area, which is free from anthropogenic pressures (Khan *et al.* 1996; Chundawat 2001; Biswas and Sankar 2002; Bagchi *et al.* 2003) to ensure survival of the introduced Lion population. Creation of a large core area free from anthropogenic disturbance also provided an ideal opportunity to study the recovery of the habitat and existing prey populations, and establish baseline information for future reference and monitoring of this important and critical habitat.

The information presented in this paper is an attempt to quantitatively assess prey base by estimating its density and biomass that could support the proposed Lion introduction in the Sanctuary.

STUDY AREA

The Kuno WLS is located between 25° 30'- 25° 53' N and 77° 07'-77° 26' E, in the Sheopur district situated in the north-west of the state of Madhya Pradesh. The total area of Kuno WLS is 345 sq. km and an additional 924 sq. km of the surrounding territorial forest is added under the same management programme. The entire area of 1,269 sq. km is now managed as Kuno Wildlife Division with an objective

to establish a second home for the Asiatic Lion. The forests of Kuno WLS represent the Northern Tropical Dry Deciduous Forest (Champion and Seth 1968) and is dominated by *Anogeissus pendula, Anogeissus latifolia, Boswellia serrata* and *Acacia catechu* with extensive Savannah woodlands forming an ideal habitat for the Asiatic Lion. The river Kuno runs through the Sanctuary and is the main source of water. The major prey species for Lion in the Wildlife Sanctuary are Chital *Axis axis*, Chinkara *Gazella bennettii*, Sambar *Cervus unicolor*, Nilgai *Boselaphus tragocamelus*, Wild Pig *Sus scrofa*, Blackbuck *Antelope cervicapra*, Four-horned Antelope *Tetracerus quadricornis* and Common Langur *Semnopithecus entellus*. Leopard *Panthera pardus*, Dhole *Cuon alpinus* and Grey Wolf *Canis lupus* are the main carnivores found in the area, apart from some occasional reports of Tiger *Panthera tigris*.

METHODS

A) Population estimation of wild prey species

Distance sampling (Anderson *et al.* 1979; Burnham *et al.* 1980; Buckland *et al.* 1993) is a widely used reliable (Anderson *et al.* 2001) method for estimating wild animal populations in the tropical forests (Karanth and Sunquist 1992; Varman and Sukumar 1995; Khan *et al.* 1996; Biswas & Sankar 2002; Bagchi *et al.* 2003).

We used both foot and vehicle transects to monitor and estimate herbivore densities in the Kuno WLS. Seventeen line transects were monitored, but data collected was not sufficient to estimate population densities. As a surrogate method, the extensive network of roads in the forest were used as vehicle transects to estimate prey densities. These roads were monitored on a very systematic schedule from an open hooded jeep travelling at speeds less than 20 km/hr by two observers. Vehicle transects allowed larger distances to be covered in shorter time. This facilitated sufficient sightings of animals to employ distance sampling methodology for analysis. In Kuno, animals are more active during early mornings and late evenings, hence higher encounter rate is expected, which maximises efficiency in terms of effort (Karanth *et al.* 2002). Road transects were travelled between 0545 hrs and 0820 hrs, and 1645 hrs and 1910 hrs. Nine road transects were established for monitoring wild prey and the transect lengths varied from 10 to 31 km. Each road transect was traversed several times in the months of April and May 2004. Total length covered in the entire sampling effort was 760 km. For each animal sightings on transects, data about species, group size, age class, sex and perpendicular distance from the road were recorded. Laser rangefinder was used to estimate distance of animal group from the road.

These roads were selected considering maximum coverage of the study area. Since human movement in Kuno Wildlife Sanctuary is minimal, most of the roads are mere clearings with negligible disturbance affecting animals. There was little traffic on the roads and hence we can assume a uniform distribution of animals with respect to the line (roads). However, there were limitations in this case considering the coverage of the study area by the roads and behavioural response by animals where they would have avoided or preferred the roads. Despite the shortcomings, the results can still be used as useful baselines for an area where no prior data is available on the prey base density.

For analyses, detection functions of all species were estimated separately. This was done to incorporate the effect of size and behavioural differences between species in modelling the detection probability. Empirical data were also used to test for evidence of any evasive or invasive movement of animals towards the line of movement, which were the forest roads in this case.

B) Population estimation of feral cattle

Despite successful rehabilitation of 24 villages from within the Sanctuary, a large population of livestock has been left behind. This cattle population has now become feral. This feral livestock population forms a substantial herbivore biomass and is a potential prey for the large carnivore population in the Sanctuary. This population can grow fast and may compete with wild prey population thereby affecting the habitat and wild prey recovery. Therefore, it is important to assess the size of this feral livestock population, and its regular monitoring will be necessary for the management to make crucial decisions. This feral livestock population has formed several large herds and they return to the same yarding sites (night shelter) every night. The research team conducted a detailed survey of each of the identified yarding sites (night shelter) to conduct a head count.

RESULTS

A) Population estimation of wild prey species

During the road survey 507 groups comprising of 2,334 animals were sighted, of which 1,104 could be aged and sexed. These included 823 Chital, 388 Chinkara, 122 Nilgai, 36 Sambar, 17 Four-horned Antelopes and 10 Blackbuck.

The sex ratio was found biased towards the female for Chinkara (100F:54M) and Chital (100F:42M) but this ratio was close to unity in Nilgai (100F:90M) and Sambar (100F:107M) populations (Fig. 1). The female to fawn and female to yearling ratios for all species were very low except in Blackbuck population, but it is based on a very small

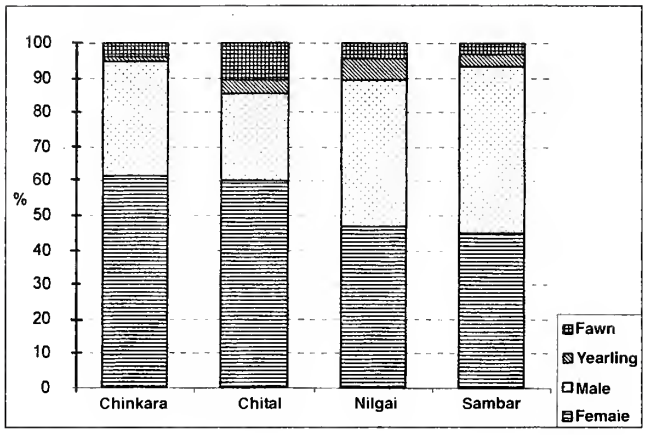

Fig. 1: Demography of main prey species in Kuno Wildlife Sanctuary

population. Female to fawn ratio ranged from a minimum of 100F:6 fawns in Chinkara to 100F:18 fawns in Chital. Similarly, yearling to female ratio was also low, ranging from a minimum of 100F:2 yearlings in Chinkara to a maximum of 100F:13 yearlings in Nilgai.

No evidence of evasive movement away from the line of movement, or aggregation of animals towards the line of movement was obtained for species other than the Chinkara, Wild Pig and Common Langur. While the histogram of Chinkara and Common Langur showed a spike near zero distance, the Wild Pig exhibited slight evasive movement or avoidance of the roads (Figs 2a-2f).

Detailed information on the group densities and group size is given in Table 1. Average group size (Table 1) of all the major prey species observed in Kuno WLS is smaller than other prey populations studied in dry forest (Khan *et al.* 1996; Chundawat 2001; Biswas and Sanker 2002; Bagchi *et al.* 2003). Largest average for group size was recorded for Chital population 4.29 (±3.51), followed by Wild Pig 4.2 (±4.83), Nilgai 2.35 (±1.86), Chinkara 1.88 (±1.18) and Sambar 1.57 (±0.9).

Table 1: Average group size of the major prey species in KWS

Species	Average Group Size	Group density	Group density CV	Standard Deviation	Range Min%	Range Max%
Chinkara	1.88	1.555	14.10	1.18	1	7
Chital	4.29	2.208	13.30	3.51	1	17
Nilgai	2.35	0.339	21	1.86	1	8
Sambar	1.57	0.231	29.70	0.90	1	4
Wild Pig	4.20	0.759	29	4.83	1	21

The density of all the wild prey, excluding Common Langur and feral cattle, in the Sanctuary is 12.11/sq. km (Table 2). The combined density of all wild herbivores, including langur (5.26/sq. km) and feral livestock (5.77/sq. km) estimated by the road transect distance sampling was 23.12 animals/sq. km. Chital is the most abundant wild prey, with a density of 6.61/sq. km followed by Chinkara. Other prey species are found in very low densities (<< 1 animal/ sq. km). Chital was also the most frequently encountered prey species followed by Chinkara, Nilgai, Sambar, Common Langur and Wild Pig. Abundance of Sambar, which is one the major prey animals of Lions in Gir forest, is relatively low in Kuno WLS.

B) Population Estimation of Feral Cattle

Cattle were found to be distributed almost in the entire Sanctuary. Initially a head count of the cattle was carried out in all of the evacuated village sites. In addition to this, cattle were also recorded during the road transect exercise. Head count of the cattle provided an estimate of 1,934 individuals in 16 yarding sites. The largest livestock population was counted in Palpur (680) and Paira (332) villages. This count translates into a density of 5.6 feral cattle/sq. km accounting for 1400 kg of biomass per square kilometre (mean weight 250 kg per cattle).

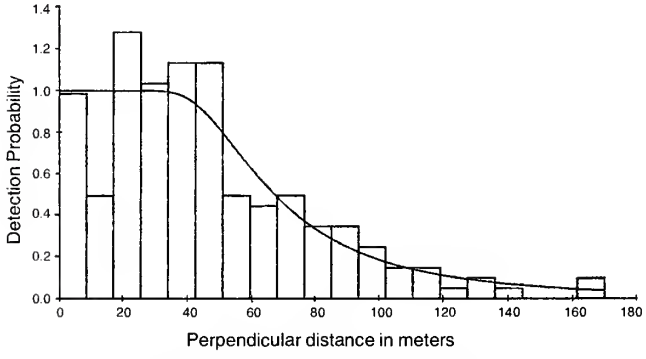

Fig. 2a: Detection Function of Chital Hazard rate model key function ($P_{chi\ square}$ = 0.49)

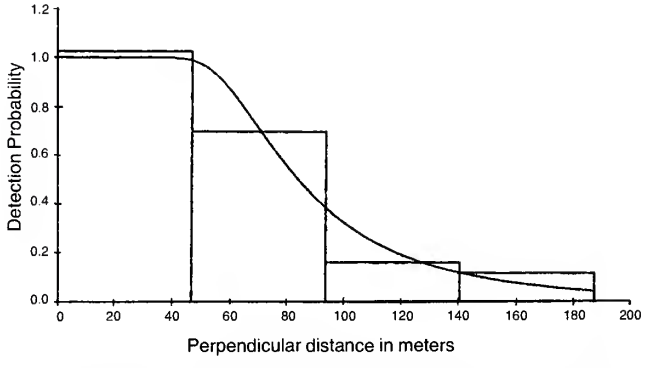

Fig. 2b: Detection Function of Nilgai Hazard rate model key function ($P_{chi\ square}$ = 0.32)

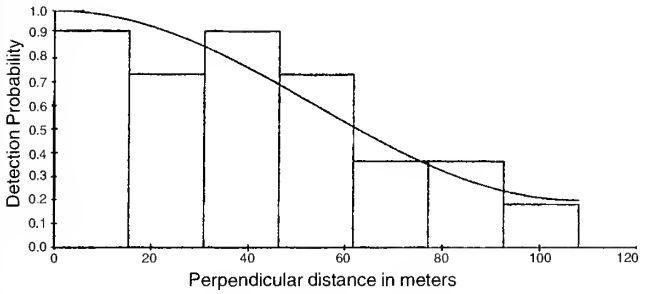

Fig. 2c: Detection Function of Sambar Uniform key function with cosine adjustment ($P_{chi\ square}$ = 0.32)

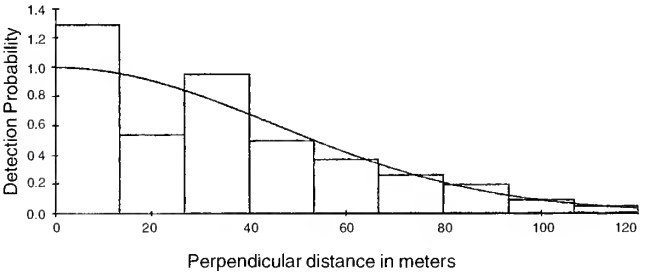

Fig. 2d: Detection Function of Chikara (note the spike in detection probability at zero distance indicating either greater visibility or aggregation of animals in the roads serving as micro habitats). Before truncation: Half normal key ($P_{chi\ square}$ = 0.66)

DISCUSSION

The low ratios of fawn and yearling to female suggests a very low recruitment and could be affecting the fast recovery of wildlife populations in Kuno WLS. These ratios are well below other documented wildlife populations of the dry forest habitat across the country (Khan *et al.* 1996; Chundawat 2001; Biswas and Sanker 2002; Bagchi *et al.* 2003). This needs to be investigated in greater detail and requires intensive monitoring to determine the ratios at birth (or ratios at first two months after fawning in October and November). In addition to this, to facilitate higher recruitment and survival in these age classes, information on mortality rates in different seasons will be critical for the management to take necessary action. Simultaneously, a detailed study to gather information on the ecological factors responsible for such low productivity of the population is essential. Since, transects were monitored at the end of the winter season, it is likely that most of the mortality had occurred by then in these age groups. The prevailing drought conditions could be responsible for most of the mortalities, and this dataset could be reflecting an unusually low female to fawn and yearling ratio. Further monthly monitoring of the prey population shall provide more detailed information and would be helpful in making appropriate management decisions.

We are considering density of groups rather than animals as one of the factors in assessing the possibility of introducing Lions in the area. Density of groups is likely to affect encounter rates of prey species and can thereby influence predators' ecology, predation, ranging, and space use patterns. Group densities of wild prey population in Kuno WLS are considerably lower than other PAs that support viable populations of large carnivores. This could be a crucial ecological factor for successful introduction of Lions in Kuno and therefore require immediate management attention.

Plots of detection probability of each species are useful to investigate various effects of animal response and distribution that may have affected the detection probability and hence density estimates. The spike can be interpreted either as an evidence of preference of roads as micro habitats or a sign of improved visibility. Similarly, evasive movement can be interpreted as the avoidance of roads or effect of disturbance due to the movement of observers. While the evasive movement away from the line of movement could be detected using the plots, it was not too profound to discard the results, and with little adjustments in the model, data was made usable. The density estimates presented here may be slightly biased due to the constraints in the methodology where we used forest roads instead of proper lines.

The density estimate of 12.11Wild ungulates/sq. km is also lower than those reported in other similar dry forest habitats (Khan *et al.* 1996; Chundawat 2001; Biswas and

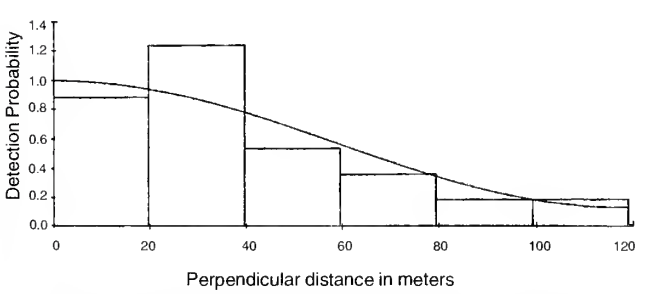

Fig. 2e: Detection Function of Wild Pig Uniform key with cosine adjustment ($P_{chi\ square}$ = 0.84)

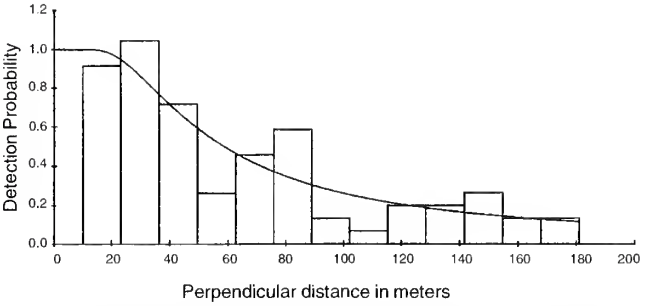

Fig. 2f: Detection Function of Common Langur (left truncation done to adjust spike) Hazard rate key model ($P_{chi\ square}$ = 0.84)

Sanker 2002; Bagchi *et al.* 2003). Among the ungulate prey species found in Kuno WLS, Chital was recorded with the highest density (6.61/ sq. km) and it accounts for over fifty percent of the entire wild prey base available (Table 2). The contribution from other major wild prey species, Sambar and Nilgai in Kuno WLS was small (only 9%). Kuno's large span of open forest habitat and mosaic of open and closed canopy forest are suitable for species like Chital, Nilgai and Chinkara and these species are widely distributed. Large and social herbivores such as Nilgai are partial to more open habitats, and therefore Nilgai and to some extend Chital can prove to be ideal prey for Lions (Chellam 1993). In a dry forest, such as the Kuno WLS, contribution from Nilgai population is substantial to the prey availability (Khan 1996; Chundawat 2001; Biswas and Sanker 2002). It can play a significant role in the ecology of introduced Lions in Kuno WLS, where large expanses of open habitats have been created after the rehabilitation of the villages. Therefore, monitoring of these open habitats in term of its recovery and utilisation by different prey population is essential to assess the suitability of these habitats in managing the introduced Lion population.

Current density estimate of wild prey in Kuno WLS is substantially lower than the reported density of 56.2 ungulates/ sq.km from Gir National Park (Khan 1996). This abundant ungulate prey biomass of Gir forest is able to support a large population of Asiatic Lion (approximately 15.86 adult Lions/ 100 sq. km) and leopards (Khan *et al.* 1996; Jhala *et al.* 1999). The predator to prey ratio estimated in terms of number of prey animals for every Lion in Gir forest is 353 wild prey animals per Lion (excluding cattle and langur). Whereas, with the current ungulate density (i.e. 12.11 animals/sq. km) in Kuno WLS, based on ratio obtained from Gir forest, the number of Lions that Kuno's wild prey base can support is just 11 or 12. Considering the low density of prey causing scattered distribution, each kill will have a higher energy cost attached to it (Gittleman 1996). This may result in increased search activity and hence introduced Lions are likely to roam widely in search of prey. During this search Lions can easily stray out of the core area, which can increase the chances of Lion entering into conflict with neighbouring human habitation on a regular basis.

Estimated abundance and biomass of wild prey alone is certainly not sufficient to support an introduced Lion population. When these density figures are used to estimate the prey biomass, it is observed that the share per Lion in Kuno will be 93 kg/sq. km of wild prey. In Gir forest this share is about 437.87 kg/sq. km, which is about five times higher (Table 3). This indicates that if Lions are introduced now, their survival and establishment will depend largely on how they respond to this limited wild prey availability in Kuno WLS. Straying in search for prey and frequent encounter with human population may not be an ideal situation for an introduction programme of a large cat.

The feral livestock population is an important prey resource for Lions in Gir forest (Joslin 1973; Chellam 1993). When taken into account as a potential prey biomass for the introduced Lion population, livestock biomass in Kuno WLS is around 1990 kg/sq. km (mean weight 250 kg per cattle). This is still far less than reported for wild prey in Gir forest, i.e. 2,784 kg/sq. km (Khan *et al.* 1996) but it is large enough to support a small introduced population of 6-10 Lions in the Kuno WLS. Livestock can at best be considered as supplementary prey. Dependence of Lions mainly on the feral livestock population has always been a debatable subject. With active management, dependence of predators on livestock can be reduced over time, and significant shifts in predator diets have been reported (Kitchener 1991; Chellam 1993) in response to enhanced wild prey availability. During the 16 years between 1973 and 1989, Chellam (1993) reports a

Table 2: Estimated density of wild ungulates, prey of proposed introduce lion population in KWS

Species	Density/ sq. km	Density CV%	95% confidence LCL	95% confidence UCL	Encounter Rate per km
Chital	6.61	15.40	4.882	8.97	0.24
Chinkara	3.62	14.30	2.736	4.803	0.17
Nilgai	0.77	23.60	0.489	1.231	0.06
Sambar	0.30	31.60	0.163	0.557	0.03
Common Langur	5.26	30.20	2.933	9.447	0.02
Wild Pig	0.79	38.90	0.373	1.682	0.1

Table 3: Estimation of prey biomass in Gir and Kuno

Species	Average Wt (in kg)	Gir National Park per sq. km		Kuno Wildlife Sanctuary per sq. km	
		Density	Biomass	Density	Biomass
Chital	47	50.8	2387.6	6.6	311.05
Sambar	134	2.00	268	0.3	40.33
Nilgai	125	0.58	72.5	0.77	97
Four-horned Antelope	21	0.42	8.82	0.02*	0.46*
Chinkara	20	2.4	48	3.6	72.5
Wild Pig	32	0	0	0.79	25.34
Common Langur	9	0	0	5.26	47.37
Total		56.2	2784.9	17.37	593.6

*(Since only 17 Four-horned Antelopes were seen in our study, it was not possible to develop a detection function and hence estimate density reliably)

substantial drop in frequency of livestock remains in scats of Asiatic Lions from 78.5% to 25.9%. Our preliminary results clearly indicate that immediate management attention and intensive monitoring of wild prey and livestock population is urgently required.

Despite the relatively high variance associated with the present estimates, herbivore density in Kuno Wildlife Sanctuary is low when we compare it with other PAs. The reason for this could be the presence of 24 villages within the Sanctuary until recently. Additionally, their livestock and a fairly large migratory cattle population coming from Rajasthan for traditional grazing till the recent past had severely affected the wildlife population and their forest habitat. Despite the strict protection and intensive conservation measures that have been initiated in the last couple of years after voluntary relocation of villages from within the Kuno WLS, it is still too early to expect a spectacular change in the wild herbivore population. But several case studies have been documented where wild herbivore populations have shown significant recoveries after removal of biotic pressures (Panwar 1991; Karanth and Sunquist 1992; Khan *et al.* 1996). In Gir, Chital population increased by 1,320% in 19 years (Khan *et al.* 1996), whereas in Kanha, it was the highly threatened *Cervus duvauceli branderi* which benefited from such management interventions (Gopal 1995).

The management of Kuno WLS has achieved a significant conservation goal by eliminating anthropogenic biotic pressure and creating a habitat suitable for Lion prey such as Chital, Sambar, Nilgai and Wild Pig. It has to be considered that recovery of these wildlife populations will take its time as documented for other PAs (Panwar 1991; Karanth and Sunquist 1992; Khan *et al.* 1996). A large feral livestock population can become a major factor affecting the recovery of the wild prey populations in Kuno WLS, if it continues to grow. For a fast recovery of wildlife population, a systematic management of feral livestock population is essential. This may reduce interspecific competition for forage, especially for Chital and provide them access to their preferred habitats that comprise mainly of ecotones and perennial water sources (Mishra 1982). Feral livestock population can at best be considered as a supplementary prey base, whereas efforts to develop a wild prey base sufficient to support the introduced Lions should be given the highest management priority. These are warranted for achieving the proposed goal of establishing a second home for the Asiatic Lions in Kuno WLS.

ACKNOWLEDGEMENTS

We are thankful to the Chief Wildlife Warden, Govt. of Madhya Pradesh for providing necessary permits to carry out the fieldwork in Kuno Wildlife Sanctuary. Our sincere thank to Shri J.S. Chauhan and the frontline staff of Kuno WLS for their help. We wish to thank the Born Free Foundation for financial support. We also thank BAAVAN and BCTI, Delhi for their support. We are also thankful to the School of Studies in Zoology, Jiwaji University, Gwalior.

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GAP ANALYSIS OF INDIAN FOX CONSERVATION USING ECOLOGICAL NICHE MODELLING

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We used ecological niche modelling to predict the geographic distribution of the Indian Fox, a canid endemic to the Indian subcontinent. This little known canid, while not yet endangered, is threatened due to rapid habitat loss and poaching throughout its range. We analysed 58 known occurrence locations from survey data collected from three states in peninsular India using the software Desktop GARP. We created an ecological niche model for India using vegetation and topographic data and further refined it by including 18 additional bioclimatic data sets. Based on the ecological niche modelling results, a gap analysis of protection offered to potential Fox habitat in two states of southern India was conducted by overlaying existing protected area boundaries on the refined distribution and calculating the extent of protection. Our analysis showed that the Indian Fox habitat consists primarily of low elevation semi-arid grassland, scrub and thorn forests, which rank among the most vulnerable in India owing to conversion to agriculture, industry and urban areas. The gap analysis showed that a little over 1% of predicted Fox distribution is covered by the protected area network. The under representation of these habitats is deleterious not only to the Indian Fox but also to a range of other species, such as the endangered Great Indian Bustard, Indian Grey Wolf and Blackbuck.

Key words: Indian Fox, *Vulpes bengalensis*, ecological niche modelling, gap analysis, distribution, protected areas

INTRODUCTION

The Indian Fox *Vulpes bengalensis*, a canid endemic to the Indian subcontinent, is widespread, ranging from the foothills of the Himalaya in the north to the southern tip of the Indian peninsula, and from Sindh Province of Pakistan east to Bangladesh (Johnsingh and Jhala 2004; Gompper and Vanak 2006). Even though this species is believed to be common (Johnsingh and Jhala 2004), little is known about its ecology or the details of its geographic distribution, or population status. The IUCN Canid Specialist Group classes this species as 'Least Concern,' (Johnsingh and Jhala 2004); it is listed under Schedule II of the Indian Wildlife (Protection) Act,1972 (as amended up to 2002), which prohibits hunting of this species (Anonymous 2002). Despite this protection, Indian Fox populations are declining owing to habitat loss from conversion to intensive agriculture, industry and development projects (Johnsingh and Jhala 2004).

The Indian Fox is found in semi-arid, flat or undulating terrain in biogeographic zones 3, 4 and 6 of India (Rodgers *et al.* 2000), which are typically drier biomes characterised by low rainfall, scrub, thorn, or dry deciduous forests or short grasslands (Manakadan and Rahmani 2000; Rodgers *et al.* 2000; Vanak 2005). Indian Foxes avoid dense forest, steep terrain, tall grasslands and true desert (Prater 1980; Johnsingh and Jhala 2004). Recent surveys indicate that though the species is widespread, it is not common through most of its range and is encountered at highest frequencies in protected semi-arid short grasslands and dry scrub areas (Vanak 2003, 2005; Vanak and Gompper 2007). Although these habitats rank among the most endangered in India (Rahmani 1989) and are subject to constant human encroachment, they are rarely the focus of conservation attention. Moreover, these habitats have been categorised as wastelands by various land management agencies and are subject to intense pressure to be transformed into agricultural and pastoral landscapes (http://dolr.nic.in/wasteland.htm accessed on January 28, 2008).

In the southern Indian states, Indian Fox habitats are decreasing, and the continued survival of the species is seriously threatened (Johnsingh and Jhala 2004). Despite a reported presence in some protected areas (PAs), most populations of this species remain outside the PA network (Vanak 2005). In the absence of systematic proactive efforts for its conservation, this species might suffer a substantial reduction in potential habitat, affecting its future survival. We thus developed a gap analysis of the protection currently afforded to Fox distribution areas in the southern Indian states of Karnataka and Andhra Pradesh.

Gap analysis is a proactive approach to planning timely action for species conservation that focuses on evaluating the degree to which native species are represented in PAs. Species not adequately represented in the existing PA network constitute 'gaps' in the conservation program. Gap analysis is intended to prevent additional species from becoming threatened or endangered, and in this sense is proactive, rather than reactive (Scott *et al.* 1993; Flather *et al.* 1997; Davis *et al.* 1998).

Mapping the distribution of a species exhaustively through on-ground surveys would be prohibitively expensive and time-consuming, if not simply impossible. The alternative used here is that occurrence data available from regions sampled in detail can be used to reconstruct the species' overall distributions using Ecological Niche Modelling (ENM) (Peterson and Kluza 2003; Peterson 2005). The ecological niche of a species can be defined as the set of ecological conditions within which it is able to maintain populations without immigration (Grinnell 1917; Holt and Gaines 1992). Several approaches have been used to approximate species' ecological niches (Austin *et al.* 1990; Walker and Cocks 1991; Scott *et al.* 1996; Scott *et al.* 2002); of these, one that has seen considerable testing is the Genetic Algorithm for Rule-set Prediction (GARP), which includes several inferential approaches in an iterative, evolutionary computing environment (Stockwell and Peters 1999). All modelling in this study was carried out on a desktop implementation of the GARP algorithm (Stockwell and Noble 1992; http://www.lifemapper.org/desktopgarp).

MATERIAL AND METHODS

Ecological Niche Modelling (ENM) has been used in numerous applications and subjected to various tests, based on diverse analytical approaches (Miller 1994; Csuti 1996; Tucker *et al.* 1997; Gottfried *et al.* 1999; Manel *et al.* 1999a,b). The particular approach to modelling species' ecological niches and predicting geographic distributions used here (summarised below) is described in detail elsewhere (Stockwell and Peters 1999; Peterson *et al.* 2002). Previous tests of the predictive power of this modelling technique for diverse phenomena in various regions have been recorded elsewhere (Peterson 2001; Peterson *et al.* 1999; Peterson *et al.* 2002; Peterson and Vieglais 2001; Anderson *et al.* 2002, 2003; Stockwell and Peterson 2002).

GARP works in an iterative process of rule selection, evaluation, testing and incorporation or rejection: first, a method is chosen from a set of possibilities (e.g. logistic regression, bioclimatic rules), and is then applied to the training data, and a rule is developed; rules may evolve by a number of means (e.g. truncation, point changes, crossing-over among rules) to maximise predictability. The predictive accuracy is then evaluated based on 1,250 points resampled with replacement from the intrinsic testing data and 1,250 points sampled randomly from the study region as a whole to represent pseudo-absences. GARP is designed to work based on presence-only data; missing information is included in the modelling via sampling of pseudo-absence points from the set of pixels where the species has not been detected (Stockwell and Peters 1999). The change in predictive accuracy from one iteration to the next is used to evaluate whether a particular rule should be incorporated into the model, and the algorithm runs either 1,000 iterations or until convergence.

We used 58 unique point occurrences of the Indian Fox sampled from the states of Karnataka, Andhra Pradesh and Maharashtra, in 2003 and 2005 (Vanak 2003, 2005) (Fig. 1) for analysis. We used 'monthly' composites of the maximum Normalised Difference Vegetation Index (NDVI) images from the Advanced Very High Resolution Radiometer (AVHRR) satellite (Eidenshink and Faundeen 1994) for 2003, as well as elevation, slope, aspect and Compound Topographic Index (CTI) from the Hydro-1K data set (USGS 2001) and a global landcover coverage (Hansen *et al.* 1998, 2000). All environmental datasets were resampled to pixels of about 1 km × 1 km for analysis.

Table 1: Bioclimatic variables used for refining the distribution of the Indian Fox in the two southern states

Sr. No.	Predictor Variables	Source
1.	Mean monthly precipitation	WorldClim
2.	Mean monthly temperature	WorldClim
3.	Maximum monthly temperature	WorldClim
4.	Minimum monthly temperature	WorldClim
5.	Annual mean temperature	WorldClim
6.	Mean diurnal range (mean of monthly max temp-min temp)	WorldClim
7.	Isothermality (Feb precipitation / July precipitation) * 100	WorldClim
8.	Temperature seasonality (standard deviation *100)	WorldClim
9.	Max temperature of warmest month	WorldClim
10.	Min temperature of coldest month	WorldClim
11.	Temperature annual range	WorldClim
12.	Mean temperature of wettest quarter	WorldClim
13.	Mean temperature of driest quarter	WorldClim
14.	Mean temperature of warmest quarter	WorldClim
15.	Mean temperature of coldest quarter	WorldClim
16.	Annual precipitation	WorldClim
17.	Precipitation of wettest month	WorldClim
18.	Precipitation of driest month	WorldClim
19.	Precipitation seasonality (coefficient of variation)	WorldClim
20.	Precipitation of wettest quarter	WorldClim
21.	Precipitation of driest quarter	WorldClim
22.	Precipitation of warmest quarter	WorldClim
23.	Precipitation of coldest quarter	WorldClim

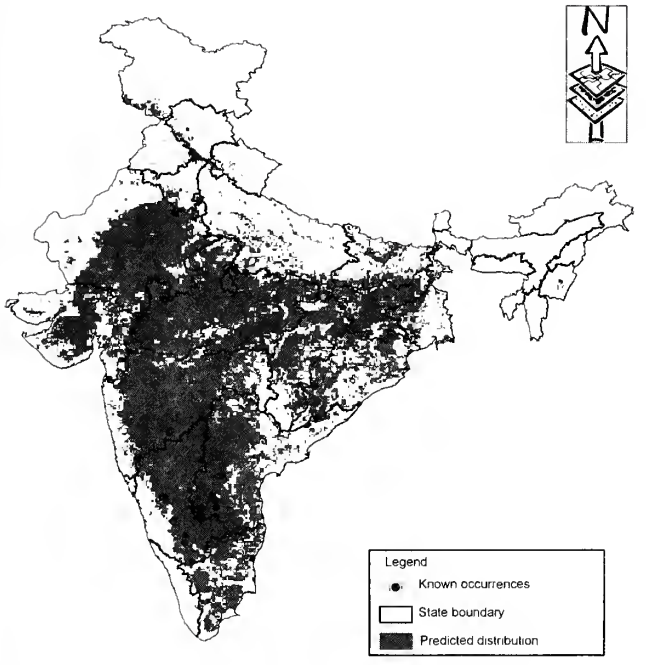

Fig. 1: Predicted distribution of Indian Fox *Vulpes bengalensis* in India based on NDVI and topographic variables
Note: The Model over-predicts distribution in some areas, such as north east India and Kashmir, where the species is not reported to occur

An arbitrary set of 100 model runs was developed for each analysis. In general, 25% (*c.* 14 points) of available occurrences were used for rule development (training data) and 25% (*c.* 14 points) for rule selection and refinement (intrinsic testing data), and the remaining 50% (*c.* 29 points) point locations were set aside for an independent test and filter of best quality models (extrinsic testing data). To choose the best models from among the 100 replicates, we filtered models on the basis of omission and commission error estimates, following recent recommendations (Anderson *et al.* 2003). First, 20 models with 0% omission errors were chosen, and of these 10 models within the central 50% of the commission values were selected as the best models.

Table 2: Predicted distribution of Indian Fox *Vulpes bengalensis* across landcover types in India

Landcover type	Location equivalent	Landcover types within Fox distributional range (%)	Fox distributional range across each land cover type %
Water	Water	0.2	2
Woodland	Deciduous forest	0.3	1
Wooded grassland	Open scrub forest	50.0	33
Closed shrubland	Tropical thorn Forest	23.6	62
Open shrubland / grassland	Grassland	23.7	29
Cropland	Cropland	2.1	3
Bare-ground	Bare-ground	0.2	1

To provide an independent validation of model performance, we randomly created four independent replicates of 40 point locations each from the original data set (n= 58). The remaining 18 points of each of these replicates were set aside for an independent test of the predictive accuracy for each replicate. Coincidence between independent testing points and model predictions for each replicate was used as a measure of model predictive ability. Binomial tests were used to compare the observed predictive success with that expected under random (null) models of no association between predictions and test points. The test results are in the form of a 'ramp' of model agreement from 0 (all models predict absence of 18 validation points) to 10 (all models predict presence of 18 validation points). Therefore, for each replicate, we calculated binomial probabilities at each of the 10 predictive levels (Anderson *et al.* 2003).

To characterise modelled distributions further, based on the existing knowledge of the species' habitat preferences, we overlaid the predicted Fox distribution on a global landcover data set (Hansen *et al.* 1998, 2000) for all of mainland India and calculated proportions of landcover types within the predicted distribution.

Since the potential distribution of the Indian Fox is limited in southern India and is decreasing, given growing urbanisation, change in land use patterns and human-induced disturbance (Johnsingh and Jhala 2004), we developed a gap analysis for the species with respect to the PA network within the states of Andhra Pradesh and Karnataka. We obtained PA boundaries for the two states and updated/corrected them using topographic maps. We repeated the modelling process by restricting ourselves only to the geographic limits of Karnataka and Andhra Pradesh to limit overprediction. We additionally incorporated 19 'bioclimatic' variables (Hijmans *et al.* 2004) in the analysis to improve the algorithm's resolving power and to obtained a refined estimate of the Fox distribution within the two states. We then overlaid existing PA boundaries to determine gaps in the protection of Indian Fox habitat. The reason we have done this for only these two states is that this is where the majority of the data comes from, and this allows us to better represent Fox distribution within a smaller geographic area. We believe the coarser analysis at a larger scale allows us to delimit the broader distribution of the species at a countrywide level, while the refined analysis allows us to overcome the inherent over-prediction of GARP distribution for gap analysis at the state level.

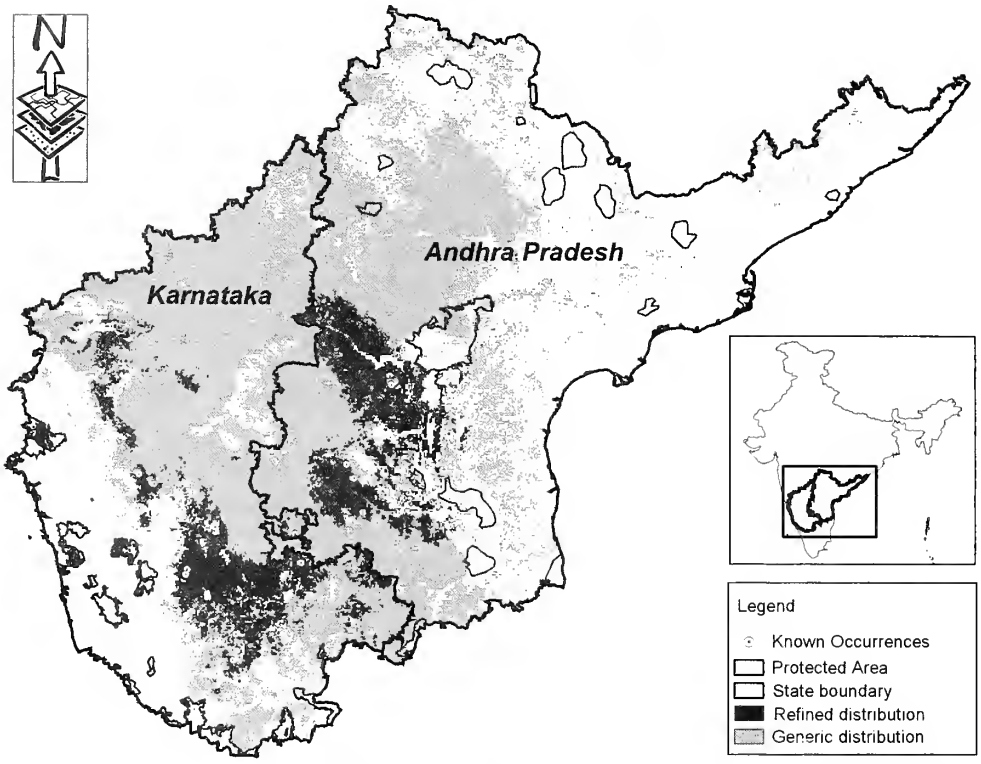

Fig. 2: Predicted distribution of Indian Fox *Vulpes bengalensis* in India based on NDVI and topographic variables

RESULTS

We used model stacking to combine the results of the 10 best models for predicting the distribution of the Indian Fox. Independent validation of the predictive success of these models ranged from 11 to 18 correctly predicted occurrences out of the 18 testing points for each of the four replicates. Binomial probabilities at each of the 10 predictive levels in all cases (4 replicate tests x 10 predictive levels each) were significantly better than random (binomial tests, all $P << 0.05$). This success in predicting independent tests of occurrence data gave confidence in the model accuracy; as a result, we used all available points to develop final models (Fig. 1).

Further exploration of these final models illustrated the species' potential distribution in ecological dimensions. The Indian Fox occupies an elevation range of 100-900 m with low rainfall (500-1,000 mm) and moderate annual mean temperatures (25-30 °C). Peak NDVI values of the post-monsoon season (0.5-0.8) correspond closely to areas holding wooded grasslands, scrub and thorn forest systems. Cross-tabulating the predicted distribution with landcover data showed that 'open scrub forest' (50%) and 'grassland and tropical thorn forest' (47%) were the dominant representative landcover types within the species' distributional area (Table 2). Focusing within Andhra Pradesh and Karnataka and adding in the bioclimatic variables, the predicted distribution of the species was further refined to 4,70,951 sq. km (9%) of the total area of the states (Table 3, Fig. 2).

Overlaying the protected area network of the two states on the refined distribution map revealed that only seven PAs

Table 3: Area statistics of Indian Fox *Vulpes bengalensis* distribution in the states of Karnataka and Andhra Pradesh, India

	Area (sq. km)	% of refined distribution	% of generic distribution	% of state geographic area
Karnataka (Geographic area – 1,92,493 sq. km)				
Total generic distribution	1,11,403			58
Total refined distribution	21,324		19	11
Total area (2 PAs) protected	92.13	0.43	0.08	0.05
Andhra Pradesh (Geographic area – 2,78,458 sq. km)				
Total generic distribution	1,04,270			37
Total refined distribution	21,833		21	8
Total area (5 PAs) protected	495.51	2.27	0.48	0.18
Combined total area protected for both states	587.64	1.36	0.27	0.12

coincided with some part of the predicted range, protecting approximately 588 sq. km (*c.* 1%) of the species' potential distribution.

DISCUSSION

The predicted range of the Indian Fox developed here agrees well with current knowledge of the species' distribution (Johnsingh and Jhala 2004). It excludes regions such as the Himalaya, the deserts of Rajasthan and the hill ranges of the Western and Eastern Ghats, from where the species has never been reported (Gompper and Vanak 2006) (Fig. 1). Despite the geographically limited sampling (limited areas in three states from peninsular India), the model performed well in capturing the species' ecological niche, as well as its geographic distribution, across a much broader region. Studies elsewhere have demonstrated a similar predictive performance of the GARP algorithm based on small numbers of training locations (Peterson 2001; Anderson *et al.* 2003; Peterson and Kluza 2003).

Our original models (NDVI and topography) predicted about 46% area of Karnataka and Andhra Pradesh as suitable (Table 3) while the analysis using an additional 19 variables permitted us to refine distributional estimates for this species, reducing it to 20% of the total extent of the states as the potentially suitable range. This analysis confirmed that low elevation grasslands, open scrub forest and tropical thorn forest constitute the bulk of the distribution of this species. These habitats also rank among the least represented in the Indian PA network (Rodgers *et al.* 2000). A clear demonstration of this under-representation is that only a little over 1% of the species' distribution potential in the two states is within the PA system.

It is therefore clear that key habitats for the Indian Fox are inadequately represented in the PA network of the states of Karnataka and Andhra Pradesh. A greater representation of dry-land biomes in the PA network would be positive, not only for the Indian Fox but also for other obligate dry grassland species such as the endangered Indian Bustard *Ardeotis nigriceps*, Indian Grey Wolf *Canis lupus pallipes*, and Blackbuck *Antilope cervicapra*. We suggest that this kind of predictive distributional modelling be used by conservation planners to identify crucial habitats for the protection of these endangered species.

ACKNOWLEDGEMENTS

The first author was supported by a Wildlife Conservation Society-India Program Small Grant, and logistic support was provided by the Centre for Wildlife Studies, Bangalore. The second author acknowledges the support of the Ministry of Environment and Forests, Government of India, and the Andhra Pradesh and Karnataka state forest departments for permits. The Ford Foundation and the Indo-US Science and Technology Forum provided support.

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ECOLOGY AND BEHAVIOUR OF AN ENDEMIC TREESHREW *TUPAIA NICOBARICA* ZELEBOR 1869 ON GREAT NICOBAR ISLAND, INDIA

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The Nicobar treeshrew *Tupaia nicobarica* is an endemic mammal restricted in its distribution to Great and Little Nicobar islands in the Andaman Sea. This article aims to report basic information on the ecology and behaviour as well as a preliminary population assessment of this species on Great Nicobar Island. Nicobar treeshrews spend more than 60% of the day foraging, followed by resting or sleeping (12%). The proportion of time spent on major activities was significantly different across different time periods, with much of the feeding activity in the mornings and evenings. Nicobar treeshrews were observed largely solitarily or as breeding pairs. Observations on mating, aggression and vocalisation are also reported. Most of the ecological and behavioural traits are shared with one or more species of *Tupaia* in the region. Observations on this species point to its extreme arboreality in comparison to other *Tupaia*. The species also exhibited a high degree of insectivory during the study period. A combination of these two traits makes this species one among a handful of nonvolant foliage gleaning insectivorous small mammals that exist in the world today. The species was observed in moderate numbers both in the littoral forests as well as in the rainforests in the interior of the island. Although formally classified as endangered (on account of its restricted range), the species is common locally. The current status of the species seems to be stable in the Great Nicobar Island which has some of the best preserved forests in India.

Key words: activity pattern, social organisation, arboreality, population assessment, breeding pairs, solitary individuals

INTRODUCTION

Treeshrews (Order Scandentia, Family Tupaiidae) are a group of tropical small mammals found in South and Southeast Asia. Treeshrews have been previously classified under different orders including Primates and Insectivora, and are considered by some to resemble primitive mammals. Currently they are classified under the Order Scandentia (Family Tupaiidae) and includes 19 species distributed among five genera (Anderson and Jones 1984). Molecular evidence supports their clustering as a separate order but places Scandentia along with Lagomorpha (which belongs to the cohort Glires, a sister group of Primates) (Schmitz *et al.* 2000). Treeshrews also belong to one of the four superordinal clades (rodents, primates, flying lemurs and lagomorphs) (Murphy *et al.* 2001). The present classification of treeshrews recognises two subfamilies: Tupaiinae (including the genera *Tupaia*, *Anathana*, *Dendrogale* and *Urogale*), and Ptilocercinae (with the genus *Ptilocercus*) (Luckett 1980; Wilson 1993). Zoogeographic, systematic and behavioural investigations concerning many of the species are ongoing. Although a large number of laboratory studies on captive Treeshrews have been carried out, field observations have been limited to a few studies (D'Souza and Martin 1974; Chorazyna and Kurup 1975; Kawamichi and Kawamichi 1979; Langham 1982; Dans 1993; Emmons 2000; Oommen 2002). Recent studies on the ecology and behaviour of these species have yielded many insights into their ecology including the unique absentee parental care system (Emmons 2000). Many tupaiids survive in tropical forests where human activities are increasing and, therefore, efforts need to be made to understand their status, ecology and behaviour in order to frame management guidelines and strategies for their conservation.

Treeshrews are entirely confined to South and Southeast Asia, and the latter region has the largest number of species. Of the three species found in South Asia, two are confined to the mainland, namely the Madras Treeshrew (*Anathana ellioti* Waterhouse 1849) in peninsular India and the Northern Treeshrew (*Tupaia belangeri* Wagner 1841) in north-east India extending into Myanmar. The Nicobar Treeshrew *T. nicobarica* is a small tupaiid with a restricted range and is found only on two islands (Little and Great Nicobar islands with an area of 150 sq. km and 995 sq. km respectively) in the Andaman Sea. Two subspecies have been described: *T. nicobarica nicobarica* Zelebor, 1869 (on Great Nicobar

Island) and *T. nicobarica surda* Miller 1902 (on Little Nicobar Island).

The Nicobar Treeshrew (henceforth Treeshrew) has been classified as 'Endangered' in the World Conservation Union – IUCN's Red List of Threatened Species (CBSG CAMP Workshop, India 2000). Here, we present results from the first field study of the Treeshrew, summarising findings on the ecology and behaviour of the species. We also compare the ecology and key behavioural characteristics of this species with other treeshrew species that have been studied elsewhere in the Southeast Asian region. Finally, we present a preliminary population assessment of the species.

STUDY AREA

The Andaman and Nicobar islands are situated in the Bay of Bengal between India and Myanmar and run parallel to the coast of Myanmar. Geologically, they are the summits of a submarine mountain range lying on the great tectonic suture zone extending from the eastern Himalaya to the Arakan coast and to Sumatra and the Lesser Sundas. The Nicobars are separated from the Andaman group by the Ten Degree Channel, and the biogeographical characteristics of these islands are an intermixture of the two biogeographic hotspots that border each other in the region. In terms of primary affinities, the flora and fauna of the Andaman Islands are similar to that of the closest biogeographical unit, the Indo-Burma hotspot. The Nicobar Islands form a part of the Sundaland hotspot (Davis *et al.* 1995). However, these affinities are also taxa dependent, as studies on groups such as birds and plants have shown (Elwes 1873; Ripley and Beehler 1989; Davis *et al.* 1995).

The Great Nicobar Island, with an area of 995 sq. km is situated at 6° 45'-7° 15' N, 93° 38'-93° 55' E in the Bay of Bengal. It is the southern most island of the Nicobar Archipelago, and is separated from the rest of the group by the Sombrero Channel. Temperatures in the Nicobar group of islands range from 22 °C to 32 °C, and the mean annual rainfall varies from 300 cm in the south to 380 cm in the northern region. April is the hottest month. The area comes under the influence of the South-west monsoon from late May; January, February and March are comparatively dry. The island is subject to occasional gales and cyclonic storms. Unlike other islands in the archipelago, Great Nicobar has perennial rivers (Alexandria, Dagmar and Galathea).

Although politically a part of India, the geographical proximity of the island is to the South-east Asian region. The biogeographic affinities (primarily floristic affinities) are to a large part to that region. The distance from the southern tip (Indira Point) of Great Nicobar to the mainland of Sumatra is approximately 100 km. The Nicobar islands host a highly diverse flora and fauna, many of which, including the Nicobar Treeshrew, are endemic. Other endemics include a subspecies of Wild Pig and the Crab-eating Macaque. Species level endemism is high, but many genera and families, including those of the Treeshrews are shared with the nearby island of Sumatra and much of Southeast Asia. Recent estimates of natural vegetation cover on Great Nicobar range from 86% to 93.5%, and although only a small percentage of forests has been lost till date, habitat conversion poses potential dangers to the island (Sankaran 1997; Gupta *et al.* 2004).

This study was carried out in areas within and adjacent to the Galathea National Park on Great Nicobar Island. The intensive study area was a small 5 sq. km patch of littoral forest where it was easy to locate and observe the animals. Basic population assessment surveys were also carried out in other areas of the island excluding the northern part. These included sites with both littoral as well as inland evergreen rainforest. Specific localities that were surveyed include Galathea, Indira Point and surrounding areas on the southernmost tip of the island, Kophen Heat and surrounding areas and the East–West Road to Shompen Hut.

The intensive study area was characterised by lower forests of littoral woodland. Mangroves and *Pandanus* vegetation was adjacent to the beach and further away mixed evergreen forests intruded into the patch. Dominant species in these mixed littoral forests included *Pandanus leram* var. *andamanensium, P. odoratissimus, Thespesia populnea, Barringtonia asiatica, Pongamia pinnata, Artocarpus gomeziana, Terminalia cattapa, T. bialata,* and *Lagerstoemia ovalifolia.* The interior evergreen rainforests had a luxuriant canopy with tall evergreen trees including *Calophyllum soulattri, Sterculia macrophylla, Planchonella firma, Palaquim semarum* and *Knema andamanica.*

METHODS

The field study was carried out in the Galathea National Park of Great Nicobar Biosphere Reserve between October 2001 and February 2002. The Treeshrews were common in closed canopy forests and were easily located by their loud piercing calls. Space utilisation and behavioural observations were made mostly by instantaneous scans covering a period of 25 hours. A minimum target for each 3 hour time period of the day (0500-0800 hrs, 0800-1100 hrs, 1100-1400 hrs, 1400-1700 hrs) was 60 scans. Sunrise and sunset were at approximately 0500 hrs and 1700 hrs respectively (Great Nicobar Island follows Indian Standard Time). During each sampling period, the activity of the animal/ animals was noted at 3 or 5 minute intervals, picked randomly. These data were

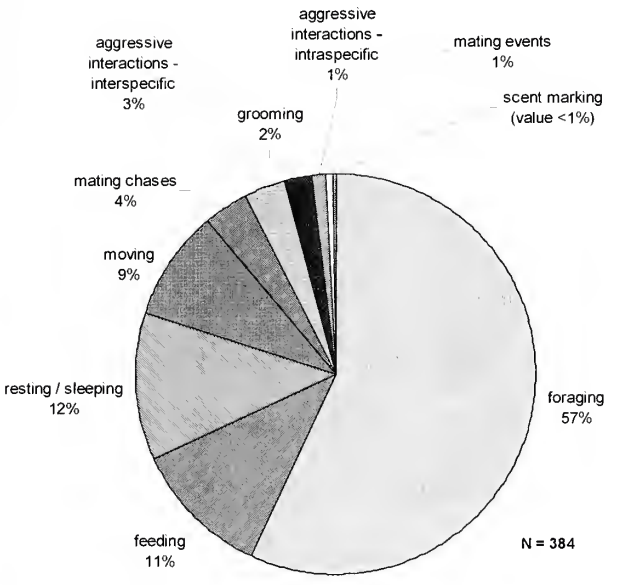

Fig. 1: Overall activity budget of the Nicobar Treeshrew

utilised to determine the proportion of time the animals spent in general activities such as foraging, resting and moving. Instantaneous scan periods covered 25 hours, and the activity was recorded for approximately 360 scans (28 sessions). Focal animal sampling was also carried out to accurately record rare events, and to identify behavioural traits that were difficult to detect during instantaneous scans. These included recording actual feeding successes, mating, grooming, scent marking and interactions with same or different species. Focal animal sampling data were collected for a total of 6 hours 24 minutes.

Population assessment was carried out in selected sites on the island. Distance constrained sampling was carried out in six sites, (three in the southern part, two in the western part, and one in the east central part of the island). Transects were walked in the morning on good weather days along existing roads and trails. The total distance covered was 21.3 km. Locating animals in both the dense canopy rainforest as well as the coastal forests was easy as Treeshrews call frequently, and their presence is also indicated by that of Greater Racket-tailed Drongo (these birds also call characteristically), which exhibit commensal feeding. All calls and sightings were recorded along with sighting angles and perpendicular distances. Initial population estimates are represented as encounter rates based on call counts.

Body measurements were available only from a single dead individual. Body measurements included head and body length (HB), measured as the length from the tip of the nose to the anus, tail length (T) measured from anus to tip of tail excluding protruding tail hairs and hind foot length (HF) or length from heel to longest toe excluding claws.

RESULTS

Morphology

Treeshrews resemble squirrels in general appearance but have different distinguishing features, the most distinct being their long snouts with an absence of vibrissae and typical dentition (the dental formula is i2/3, c1/1, pm3/3, m3/3 * 2 = 38). *T. nicobarica* resembles *T. glis* in appearance. The dorsal portion from the nape to tail tip is uniformly dark brown to russet in colour, there are no prominent facial or shoulder markings, the region from the nape to snout is lighter brown, and so are the limbs. The underside is much paler in comparison to the dorsal portion. Measurements of a single adult male were obtained: HB = 135 mm; T = 180 mm; HF = 28 mm; weight = approx. 80 g. The skull and jaws of the specimen which we found were crushed and too disfigured to take exact measurements. *T. nicobarica* is likely to be the smallest among the three South Asian Treeshrews and also likely to be among the smallest tupaiids.

Activity patterns

Instantaneous scan data were analysed to construct a behavioural repertoire of the species. Treeshrews spend more than 60% of the day foraging (feeding or searching for food) followed by resting or sleeping (12%), but it is important to note here that for a 12 hour span, this amounts to 10 hours 34 minutes of activity and only 1 hour 26 minutes of actual resting time (Table 1). Focal animal sampling provided information on other activities such as actual feeding events, mating, grooming, scent marking and interspecific interactions. The activity patterns of breeding pairs were on the whole similar to those of solitary individuals; pairs rested more often than solitary individuals and mostly after mating

Table 1: Activity patterns during different sampling periods

Activity	0500-0800 hrs (73 Scans)	0800 1100 hrs (75 Scans)	1100-1400 hrs (158 Scans)	1400-1700 hrs (78 Scans)
Foraging	71.2	49.3	47.5	70.5
Feed	11.0	17.3	8.9	9.0
Rest / sleep	1.4	8.0	24.7	-
Groom	2.7	2.7	2.5	1.3
Scent mark	-	-	-	1.3
Move	4.1	10.7	7.6	14.1
Mating chases	-	4.0	7.0	-
Mating	-	-	1.3	-
Aggression - intraspecific	5.5	-	-	-
Aggression - interspecific	4.1	8.0	0.6	3.8

(Table 2, Fig. 1). Resting activity of solitary individuals was mostly during rains. The number of actual recorded feeding events was also lower for pairs as they devoted attention to mating and associated activities.

The proportion of time spent under major activities (foraging, feeding, resting, moving and mating activities) was significantly different across different time periods ($\chi^2 = 76.20$, $p < 0.05$, $df = 15$). As expected, foraging activity was more during morning and evening scans, i.e. soon after the animals came out or just before they retired. Resting or sleeping was recorded almost entirely in the late morning or afternoon scans. Bad weather affected foraging activities adversely; the animals were less active during rain than in sunny weather ($\chi^2 = 28.28$, $p < 0.05$., $df = 6$). There was an increase in resting activity and decrease in combined foraging and feeding activities during rainy weather (N=384) (Fig. 2).

Resting during daylight hours could be classified into two types: the animals pausing while foraging, usually sitting still on branches (average duration = 25 seconds, n=5); and longer resting periods involving solitary individuals or breeding pairs curling up on branches and sleeping for longer periods of time (average duration 13 minutes). Breeding pairs rested more often, and soon after mating. The average diurnal resting time (for long periods of rest) calculated for the study period was 1 hour 26 minutes for all individuals put together, 1 hour 12 minutes for solitary animals and 1 hour and 48 minutes for breeding pairs. These values incorporate resting periods for the rainy days that occurred during the study also. The animals rested comfortably on branches below vine-covered canopies or subcanopies with their tails curled around the body, staying motionless and evidently sleeping. Some daytime resting sites were used repeatedly by the Treeshrews. Sleeping animals were extremely well camouflaged

Table 2: Activity patterns of solitary individuals and breeding pairs

Activity	Activity budget (%)	
	breeding pairs (212 scans)	solitary animals (172 scans)
Foraging	56	58
Resting/Sleeping	15	10
Feeding	8	15
Moving	8	10
Mating chases	7	0
Aggressive interactions-interspecific	3	3
Aggressive interactions-intraspecific	0	2
Grooming	2	2
Mating	1	0
Scent marking	0	0

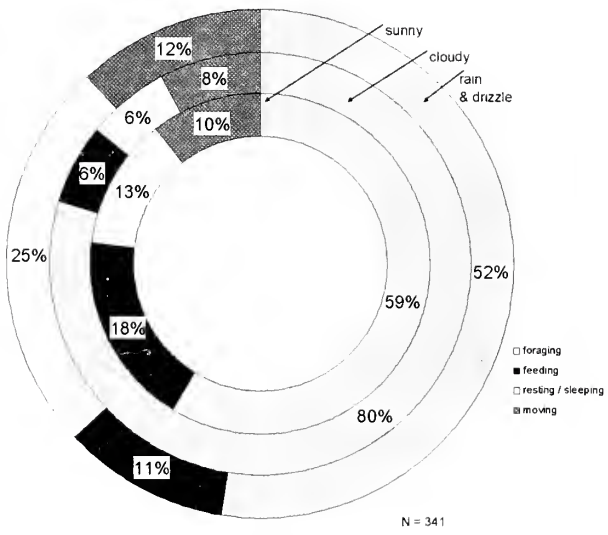

Fig. 2: Activity patterns of the Nicobar Treeshrew in relation to weather

and could only be spotted when they moved or while grooming. On two occasions, after copulation, the male was observed on top of the female (in the same position) for more than 10 minutes. Breeding pairs rested more often. Single resting sessions of animals lasted for up to 39 minutes. Some of the resting sites were exposed branches. However, it is suspected that these animals spent the nights in the thick foliage of *Pandanus* species that are found in abundance in the littoral forests of the island. No nest sites were discovered during the study, and there is no available information about the nesting of *T. nicobarica.*

Social organisation and other behavioural observations

It was observed that *T. nicobarica* moved solitarily or in pairs. Out of 311 instantaneous scans, 138 were of breeding pairs, 168 of solitary individuals and four were of two individuals of the same sex. Breeding pairs interacted often and it is suspected that they are monogamous. Individuals rested very close to each other, either with the nose of one individual touching the base of the tail of the other, or one on top of the other. It was not discovered if pairs spent the night at the same or nearby roost sites. However, it was noticed that before retiring for the night mating individuals called repeatedly to each other and moved away together in the same general direction.

Six mating events were recorded during scans (three more were recorded out of scan periods). The average duration of mating was approximately 16 seconds. Breeding pairs could be easily identified as males usually chased females while foraging and tried to mount them. The pairs seemed to be monogamous, and during one scan period the pair mated thrice within 5 minutes. Females showed aggression during

Table 3: Encounter rates from different parts of Great Nicobar Island

Area	Location	Distance (km)	Encounters	Encounter rate (per km)	Forest type
South	Indira Point to Chingen village	4	17	4.25	Littoral
	South Bay to Chingen village	4	14	3.5	Littoral
	South Bay to 36 km point	4	8, 17	2, 4.25	Littoral
West Coast	Kopen Heat-Shompen Hut road	3.5	9	2.57	Rainforest
	Alexandria beach to Kopen Heat	1.8	8	4.44	Littoral
Central	Shompen Hut road (13 to 17 km)	4	25	6.25	Rainforest

mating. Both the male and female occasionally clambered over each other immediately after mating. Pairs usually rested or slept after mating.

One set of aggressive interactions was observed between two males. An approaching male disturbed a male that was feeding on insects on cane buds and the latter was chased away. The intruder was chased a long way (more than 20 m) after both animals confronted each other in close contact, screaming loudly. This interaction was bloodless and was repeated a couple of times before the intruder retreated. Females sometimes showed aggressive behaviour during mating. After copulation, some females tried to push the male away and scolded loudly. Aggression with other species was demonstrated only with bird species in the feeding association. Feeding individuals sometimes screamed, scolded and chased both drongos and sparrow-hawks that infringed on prey that was flushed.

Scent marking was a frequently observed behaviour. They frequently rubbed their ano-genital region on branches. Chest and chin marking was observed once during scans. Scent marking was observed 15 times for a total scan period of two hours. The male was also seen urinating on the female on one occasion following mating. Pairs usually rubbed against each other, especially with the chest and chin.

T. nicobarica was observed to call frequently and to make different types of vocalisations. These included single noted squeals while solitary animals were foraging and moving from place to place, continuous alarm calls in the form of squeaks in the presence of predators, loud two or three noted shrieks of protest while feeding with birds or other individuals and calls of contact between individuals of a breeding pair.

Population Assessment

Encounter rates were recorded along transects in some accessible parts of the island (Table 3). Ninety-eight individuals were recorded over a distance of 21.3 km. The majority of individuals were located by their calls. Only 2% of the records are sightings where the animals were spotted before being heard. Therefore, absolute encounter rates are likely to be underestimates, but will serve for a broad level relative comparison between localities. The largest number of individuals were recorded in the rainforests in the central part of the island (6.25/km). The littoral forests in the southern part of the island had lower encounter rates.

DISCUSSION

Activity patterns

Emmons (2000) reports that the *Tupaia* species rested sporadically after being completely active during the first two hours of the morning and the same could be said of *T. nicobarica* as well.

The time of the day had an effect on the activities of the animals, as did bad weather. On days when there was heavy rain early in the morning, the Treeshrews delayed their foraging activities. A light drizzle, however, did not prevent them from foraging in the morning hours, probably because they could not afford to rest without feeding following a long night's fast. Treeshrews in Borneo are also known to respond in a similar manner during adverse weather conditions (Emmons 2000).

Tupaia are known to be active only during the day, and this was true of *T. nicobarica* also. The individuals in the study area were observed to be active from dawn to dusk (0507 hrs to 1730 hrs) (Table 1). It may be noted that the approximate sunrise and sunset times were 0500 and 1700 hrs respectively (Great Nicobar although considerably east of the mainland India follows Indian Standard Time). On some days initial calls were heard only well after the sun had risen but on most occasions the animals foraged frantically at dusk well after 1700 hrs. The emergence time in the morning was delayed if there was heavy rain. *Tupaia* in Borneo are known to leave their nests at dawn, but evening return times varied with feeding periods and weather conditions (Emmons 2000). For *T. minor* in West Malaysia, D'Souza and Martin (1974) report different results with late emergence times, except for days after heavy rainfall, when they emerged very early to forage.

Reproductive Behaviour

No information on the reproductive activity other than observations of mating could be obtained during the study period. Treeshrews are known to exhibit the 'absentee' maternal care system, which was first observed for captive *T. belangeri* (Martin 1968) and later for captive *T. minor* and *T. tana* (D'Souza and Martin 1974). This practice was also recorded among wild *T. tana* in Borneo (Emmons 2000). The significant feature of this system is the mother gives birth to her young ones in a separate nest and visits them only for a few seconds every other day to nurse. The young ones huddle and lie motionless and noiselessly in the nest to preserve body heat. They feed hysterically (almost 1/3 rd their body weight in milk) when the mother discreetly returns for a few seconds. The young ones also groom themselves from time to time as the mother does not spend any effort in cleaning or looking after them. The nests are clean and are known not to have any particular odour that might attract predators, and the mother is also known to return to the nest cautiously and using different pathways usually in the early hours of the morning, when few predators are about. The young grow rapidly owing to the highly nutritious nature of Treeshrew milk (which is known to be second only to seals' milk in terms of fat content). They are weaned and leave the nest in 25 to 33 days, after which the mother spends time with them grooming them and providing them with food. The nesting and post-partum behaviour of this species seem to be directed at predator avoidance. Emmons (2000) describes this pattern in detail.

It is likely that *T. nicobarica* also follows such an 'absentee' system, but no information is available. The litter size of a single *T. nicobarica* individual has been reported to be one (Lyon 1913). Although mating events were recorded between November and February, it is not clear if this reflects a more seasonal pattern. *Tupaia* species in Borneo had a broad breeding season from August to November and a second one from March to May and breeding is reported to be highly related to availability of fruit and invertebrate prey (Emmons 2000). In contrast to captive situations, wild treeshrews show low overall reproduction rates, probably due to nutritional limitations (Langham 1982; Emmons 2000).

It may be suggested here that *T. nicobarica* also possibly exhibits the 'solitary ranging pair' system reported by Kawamichi and Kawamichi (1979) for *T. glis* (= *belangeri*) and probably the Bornean Treeshrews. This refers to a social system where solitary animals that form a monogamous pair form a territory and defend it against other individuals of its own gender (the Type I or facultative monogamy described by Kleinman 1977. This pattern has been reported among a number of mammals including nocturnal prosimians, pikas, elephant shrews and Maned Wolf (Emmons 2000). Like *T. minor, T. nicobarica* pairs also sometimes spent the whole day foraging and resting together. This is unlike other *Tupaia* species that interact briefly. The pairs rested together during the day, but unlike *T. minor* that rested far apart on the same trees, *T. nicobarica* seem to be strongly pair-bonded and rested close together.

Other Behavioural Observations

Adults are known to scent mark branches, tree stumps and rocks either by rubbing their ano-genital region (with urine) or the chest and chin (in males, there is a musky and oily secretion from a glandular area in the neck). While urine markings lose their effect on conspecifics in a matter of minutes, mingling with the neck gland secretion usually cause them to persist for hours or days (Thenius 1990). Parent *T. belangeri* are known to scent mark their young ones to recognise their offspring during aggressive encounters with conspecifics (von Holst 1974). Stress caused to the mother prior to or during delivery sometimes results in the protective scents not being applied and devouring of the offspring by the mother (Thenius 1990). Stress and related aspects such as hormonal changes in captive treeshrews have been extensively studied for understanding the biology of stress in humans and other primates (von Holst 1974).

T. nicobarica are generally very alert animals. They are difficult to locate when they are silent, but contrary to what Emmons (2000) reports for some Bornean Treeshrews, the study animals called loudly and frequently, and as a result they were easily located. They were also not easily alarmed unless the investigator got too close. Natural predators for this animal in this area are few, as wild cats, mustelids, viverids or other mammalian carnivores are absent. In the study area, treeshrews were noticed to be alarmed in the presence of Crab-eating Macaques *Macaca fascicularis umbrosa*, Reticulated Pythons *Python molurus* and human-beings. It is possible that they are predated on by Crested-serpent Eagles *Spilornis cheela* and the young ones could be preyed on by small raptors, reticulated pythons and rats that are found in the island. Domestic cats belonging to settlers have been known to predate on the Treeshrews. The species exhibited a unique interspecific feeding association with Greater Racket Tailed Drongos *Dicrurus paradiseus* and an *Accipiter* (probably Chinese Sparrow-hawk, *Accipiter soloensis*) (Oommen and Shanker, in review). On many occasions, the Sparrow-hawk and Greater Racket-tailed Drongos were seen waiting a few feet away from resting Treeshrews, and it is also possible that these animals benefit from the alarm calls of the birds if predators approach. However, neither Drongos nor Sparrow-hawks made any alarm calls indicating the presence of people.

On many occasions it was suspected that Greater Racket-tailed Drongos were mimicking Treeshrew calls possibly to detect and join the latter. Emmons (2000) reports of a strange similarity between the alarm calls of *T. minor,* and *T. gracilis* with those of terrestrial pittas (*Pitta baudi, P. venusta*), but speculates this is a convergent trait. Alarm calls were reported to be frequent in the more social species such as *Ptilocercus lowii, T. minor* (Emmons 2000) and *T. nicobarica* and this may be related to predator detection strategies. Eight different vocalisations have been identified in *Tupaia* by Binz and Zimmerman (1989). These include loud 'squeals' of aggression, modulating 'screams' to indicate immediate danger, 'chatters' in response to disturbances and rhythmic 'clucking' and 'whistles' associated with courtship and mating.

T. nicobarica was observed to be a highly arboreal, diurnal and mostly insectivorous species during the period that it was studied. The most primitive living treeshrew (*Ptilocerus lowii*) is strictly arboreal and so is *T. minor*, which is similar in many ways to the study species (including the nearby island of Sumatra). However, the high arboreality of the Lesser Treeshrew *T. minor* is somewhat debated. Emmons (2000) did not observe the species on the ground, whereas D'Souza and Martin (1974) reported 11% of his sightings on the ground. Arboreality seems to be an ancestral trait among treeshrews. Arboreal *Tupaia* are, however, known to be more frugivorous. Initial results indicate a very pronounced insectivorous diet for the species. Only a handful of non-volant mammal species are known to forage arboreally for insects. From the present study, it appears that *T. nicobarica* is one of them.

On account of its high arboreality, insectivory and higher sociability, it would be interesting to investigate if *T. nicobarica* is an intermediary between *P. lowi* and *T. minor.* Further studies on this species may lead to solving questions about arboreality, insectivory and absentee parental care systems, all of which in turn could throw light on their radiation patterns. The present viewpoint is that *Ptilocercus*, with its cohesive social behaviour, and arboreality could be an antecedent of prosimians, but modern *Tupaia* seem to be improbable ancestors of primates, as they seem to have radiated terrestrially rather than arboreally and have different parental care and feeding systems (Emmons 2000). The foraging behaviour of *T. nicobarica* is almost identical to that of *T. minor* as described by Emmons (2000). It moves purposefully through the vegetation inspecting all types of foliage, green or dry curled leaves, tree ferns, dead wood and bark. Trees with a large number of climbers are often visited and inspected carefully, very often the animal pauses on its hind legs and pushing against twigs with the fore legs and then leans out to investigates leaves above. The foraging intensity is very high and sometimes the animals spend hours on a single tree. The insect prey of *T. nicobarica* and *T. minor* may be similar on account of the similarity in foraging patterns and sites. Scats of *T. minor* examined by Emmons (2000) contained Orthoptera of two kinds, crickets and cockroaches (50%), beetles (21%), and caterpillars and spiders (10%). Davis (1962) and Lim (1967) also found ants. Emmons (2000) also reports that although the prey base is extremely large (being tropical rainforests), *T. minor* generally ate the most common non-flying or slow-to-fly arthropods.

T. nicobarica is similar to *T. minor* in appearance, arboreality and most of its behaviour. Therefore, it is possible that the latter may be more frugivorous during some periods, especially when fruiting peaks occur. A detailed study of the phenophases of fruit trees may be required before conclusions about the degree of frugivory of the species under study can be reached. Emmons (2000) reports that the fruit eating pattern in most species follows habitat-wide overall fruiting phenologies and that during some months they were not detected to be eating any fruits.

Conservation Status

On the basis of their geographical separation, two subspecies have been recognised: *T. nicobarica nicobarica* Zelebor 1869 on Great Nicobar Island and *T. nicobarica surda* Miller 1902 on Little Nicobar Island. Till date, molecular studies have not been carried out to examine if these populations are really distinct. The taxonomic references available for *T. nicobarica* are (1) *Cladobates nicobaricus* Zelebor 1869, Reise Novara, Zool. Theil., 1 : 17, pl. 1. figs 1, 3 and pl. 2 (2) *T. nicobarica* Blanford (1888 – 91, p. 212) Ellerman and Morrison-Scott (1951, p. 12). Napier and Napier (1967, p. 330). (3) *T. nicobarica surda* Miller 1902, Proc. U.S. Nat. Mus. 24 : 774.

T. nicobarica nicobarica and *T. nicobarica surda* have been classified as endangered (B1 & 2C) by the IUCN (1995). This status has been accorded due to the restricted distribution of the species. The combined area of occupancy for the two subspecies in The Great and Little Nicobar Islands put together is less than 1,200 sq. km. No prior population estimates were available for this species.

The numbers of *T. nicobarica* seem to be comparable to those from Southeast Asia, but since the encounter rates are underestimates, and since actual densities could not be calculated, formal comparisons are not being made. The densities of *T. glis* varied between 6-12 per ha in Thailand (Lekagul and McNeely 1977) and 2-5 per ha in Malaysia (Langham 1982). Emmons (2000) reports that for six species

of Bornean treeshrews, densities ranged from 0.13 to 1.2 individuals per ha.

There are no direct threats to the species at present. The habitat of this species is presently well protected, and in relative terms may be regarded as one of the least populated and most pristine protected areas of the country (Oommen, *in press*). The adequacy of the protected area network in this area has been examined for taxonomic groups such as birds (Sankaran 1997), and the some of the recommendations hold true for endemic mammals such as the Nicobar Treeshrew. For example, the need for protection of the southern part of the island from development activities and the inclusion of the buffer zone between the Campbell Bay and Galathea National Park into the formal protected area network as suggested by Sankaran (1997) would provide a large contiguous patch of protected forest. The treeshrews are not hunted; on the other hand Nicobari villagers keep some individual as pets. However, owing to the highly arboreal nature of the species, and due to recorded adverse effects on a similar arboreal species (*T. minor*) to selective logging, it is suggested that the canopy contiguity of the forests be maintained to ensure the survival of this species. Also, introduced carnivores, especially domestic cats are known to successfully predate on *T. nicobarica* and might decimate local populations if the number of human settlements increases. *T. nicobarica* may be regarded as a species of high conservation importance for India, as it is an endemic *Tupaia* and one of the three species of the narrowly distributed and primitive order Scandentia.

Extensive areas in both the Great and Little Nicobar islands were submerged and partially destroyed as a result of the Indian Ocean tsunami of December 2004 (Andrews and Vaughan 2005). The intensive study area at the Galathea river mouth is believed to have been entirely flooded, and the same applies for some of the other areas that were surveyed. Although some amount of habitat alteration would have taken place, it is likely that this species may not have been adversely affected at least in the interior of Great Nicobar, which has higher terrain. There have been some unconfirmed reports that a great deal of wood will be extracted from the forests to rebuild the destroyed settlements in the area. Forest Department rules at this point of time are likely to be relaxed and it may be inevitable that some amount of trees will be cut for this purpose; as the number of settlements is small, this activity may not cause significant changes. *T. nicobarica* is of interest from biological and conservation perspectives, and future studies and surveys may provide interesting insights.

ACKNOWLEDGEMENTS

The authors would like to thank Rauf Ali and Harry Andrews for suggesting the study. The Andaman Nicobar Environmental Team (ANET) and the Madras Crocodile Bank Trust generously supported this study with funds and arranged logistics. Field assistants Saw Aghue and Saw Glen are especially thanked for their contribution. We would also like to acknowledge contributions by Mr. Khazan Singh, Mr. Pratap Singh, Mr. Yesu Ratnam Nalli, Mr. Robert Pee and staff of the Forest Department, Suresh Babu of Delhi University, Manish Chandi, Shreyas Krishnan, John and others at ANET and MCBT, Commdt. Sharad Sharma, and Dr. Vinny Wilson of the Indian Coast Guard, Capt. Majumdar of the MV Sentinel, Mr. Suresh Kumar, Mr. James, and the late Mathe Budda of Kopen Heat.

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TIGER PREY IN A TROPICAL DRY FOREST: AN ASSESSMENT OF ABUNDANCE AND OF BIOMASS ESTIMATION DERIVED FROM DISTANCE SAMPLING

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Data on animal and biomass densities of Tiger prey were collected using Distance Sampling in Panna Tiger Reserve, India. Line transect surveys for Distance Sampling were conducted in 2000, 2001, 2003 and 2005 using different approaches. Animal and biomass densities from 2003 are compared with estimates available from other reserves of the Indian subcontinent. In Panna Tiger Reserve density of Tiger prey is estimated to be 46.32 animals /sq. km. Chital, Nilgai and Sambar dominate the Tiger prey population of the Reserve. In terms of number of animals, Chital is the most abundant followed by Nilgai and Sambar; however, Nilgai groups are the most frequently encountered prey. The prey biomass density estimated for the Panna Tiger Reserve is 4,057 kg/sq. km. Most of the biomass is contributed by two prey species, Nilgai and Sambar. The biomass density contribution of Chital and smaller prey is small compared to other protected areas of the Subcontinent. In terms of the number of animals, contribution by large prey, medium prey and smaller prey is almost equal in Panna. But in comparison to other Tiger habitats the contribution by Chital and other medium prey in Panna Tiger Reserve is small, both in terms of the number of animals (39.24%) and of biomass density (21.26%). However density estimates from Panna Tiger Reserve and other protected areas indicate that Tropical Dry Forests, which are the largest Tiger habitat in the Subcontinent, can support fairly high prey populations and sustain a viable Tiger population. In tropical forests, where ecological conditions vary drastically, February and March appear to be the most suitable time for Distance Sampling. To minimise the errors encountered during the surveys, a short sampling period with more lines, which are walked only once a day and repeated after a few days, is suggested.

Key words: Tiger prey, ungulates, density estimation, line transect, Tropical Dry Forest, India

INTRODUCTION

The Tiger *Panthera tigris* occupies diverse habitats and preys mainly on large ungulates (Schaller 1967; Sunquist 1981; Johnsingh 1983; Seidensticker and McDougal 1993; Karanth and Sunquist 1995; Sunquist *et al.* 1999; Biswas and Sanker 2002; Bagchi *et al.* 2003). Its abundance is governed by the availability of its prey (Karanth *et al.* 2004; Sunquist and Sunquist 1989). Recent studies indicate that loss of prey is one of the major factors affecting the viability of the Tiger populations (Karanth and Stith 1999); they further indicate that a demographically viable Tiger population can be protected, provided that its prey base is managed intensively. Therefore, in order to save Tigers in the wild, effective management of large herbivore populations is a very important conservation issue in all Tiger habitats. The Tropical Dry Forest is the largest Tiger habitat in the Indian subcontinent, but very little quantitative information is available from this ecosystem. This Tiger habitat is highly fragmented (Wikramanayake *et al.* 1998) and suffers from forest fires, poaching, competition with livestock and loss of habitat and habitat quality (Panwar 1987; Karanth 1991; Debroy 1996; Seidensticker 1997; Chundawat *et al.* 1999; Chundawat and Gogate 2001). For effective conservation measures to save Tigers in dry forests, intensive management of prey populations requires strategies to manage prey in densities that can support a demographically viable Tiger population.

Estimation of large herbivore populations in the wild has always been a very difficult task. In the past, various approaches were used which lacked robust theoretical and statistical basis (Schaller 1967; Eisenberg and Lockhart 1972; Tamang 1982; Johnsingh 1983). But, in the last decade, Distance Sampling using line transect surveys has been found very useful for estimating biological populations (Burnham *et al.* 1980; Buckland *et al.* 1993; Plumptre 2000; Anderson *et al.* 2001; Buckland *et al.* 2001; Marques *et al.* 2001). In India, Distance Sampling has been used widely in diverse forest habitats for estimation of ungulate populations (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Jathanna *et al.* 2003; Karanth *et al.* 2002; Bagchi *et al.* 2003). Different approaches employed for line surveys vary from walking transects every month to walking all lines simultaneously within a few weeks (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Bagchi *et al.* 2003). Inherent spatial and temporal variability during the sampling period can affect the precision of survey results (Thomas *et al.* 2002).

In this paper we provide information on abundance and biomass densities of Tiger prey from a tropical dry forest. In addition, the paper assesses and compares various approaches employed for estimating animal densities using line transects. We hope that these comparisons will be useful in designing future surveys to achieve better precision and reliability.

Data from these surveys are analysed to discuss the best approach and season for surveys in tropical forests, where visibility changes considerably with season and can thus affect density estimates. These data sets are also analysed to determine the efficiency of the survey without compromising assumptions. We have compared the seasonal encounter rates for "efficiency" (number of detections per km walk), detection functions and group size over time for heterogeneity. We also looked at the likely bias due to repeated visits on the same day possibly causing animal movement away from the transect line.

STUDY AREA

The Panna Tiger Reserve in central India encompasses 543 sq. km of tropical dry forest. The intensive fieldwork was carried out within approximately 350 sq. km of the Reserve. Extensive plateaux and gorges characterise the terrain of the area. Its unique step topography divides the area into the upper Talgaon and middle Hinauta plateaux and lower Ken river valley. The River Ken passes through the National Park and is the major perennial source of water. The plateaux are separated by 10-80 m high escarpments, creating several deep gorges at many places; these are characterised by steep rock faces, thick forest cover and series of caves at the base of escarpments. The average annual rainfall is 1,100 mm of which almost 60-70% falls during July and August. This is followed by a long dry spell continuing from October to June. Due to the hilly topography and long dry season, water is a major limiting factor during the summer months when temperature can regularly exceed 45 °C. There are 13 villages within the Reserve with a human and cattle population of 6,000 and 9,500, respectively.

The dominating vegetation type is "Dry Teak Forest" (C1-b, Champion and Seth 1968). The extensive dry and short grass habitats with open thorny woodlands support antelope populations of Nilgai *Boselaphus tragocamelus* and Chinkara *Gazella bennettii*. The more mesic habitats with tall grass and associated closed miscellaneous forest, mainly distributed along the major seasonal drainages, support high ungulate densities, including Sambar *Cervus unicolor*, Chital *Axis axis*, Wild Pig *Sus scrofa* and Four-horned Antelope *Tetracerus quadricornis*. The distribution of these habitats creates a diverse and very heterogeneous landscape, where ecological conditions also vary seasonally. The Tiger Reserve supports a diverse carnivore population, which includes Tiger, Leopard *Panthera pardus*, Sloth Bear *Melursus ursinus*, Dhole *Cuon alpinus*, Grey Wolf *Canis lupus*, Striped Hyena *Hyaena hyaena*, Jungle Cat *Felis chaus* and Indian Fox *Vulpes bengalensis*.

METHODOLOGY

In this study we used Distance Sampling to estimate the abundance of Tiger prey in the Panna Tiger Reserve. Line transect surveys were conducted in 2000, 2001, 2003 and 2005. Nine line transects of variable length, ranging from 1.93 to 2.85 km, were marked and prepared for silent walking. These nine lines were placed randomly covering almost all the available habitat types in the intensive study area. Care was taken to not over-clear the line for it could have caused a spike at zero distance (animals using lines as walkways), which is hard to model (Buckland *et al.* 2001; Gangadharan 2005). These transects were walked between sunrise and 0930 hrs and between 1500 hrs and sunset. For every sighting of a group, information on species, number of individuals, radial distance (with the help of a laser range finder), and radial angle were recorded.

In 2000, these nine line transects were walked in the morning twice every month from October to June. Later, this approach was modified and in 2001, all the lines were walked simultaneously every morning and evening, for 15 days in March. Further modification was made in the 2003 survey: only three lines were walked simultaneously morning and evening, and these were repeated every fourth day in February and March. Thus, in total 24 (12 days x 2 times a day) temporal replicate surveys for each line were conducted. In 2005, to test the effect of repeated walks on the same day (19 field days), on density estimates, we walked the same line in the morning and later in the evening after a gap of more than two days. The exercise was done for 19 field days.

For analysis of data, the computer program DISTANCE 4.1 (Thomas *et al.* 2003) was used. Biomass densities of Tiger prey were calculated for each survey. Data from the survey of 2003 was used to compare estimates documented from other habitats of the Indian subcontinent.

Analysis:

We followed the standard procedures for analysis described in Buckland *et al.* (2001) and Thomas *et al.* (2003). For density estimates and related analyses concerning variance, the nine transect lines were considered as spatial replicates, and all the temporal replications on particular transect lines were pooled. We estimated encounter rates of

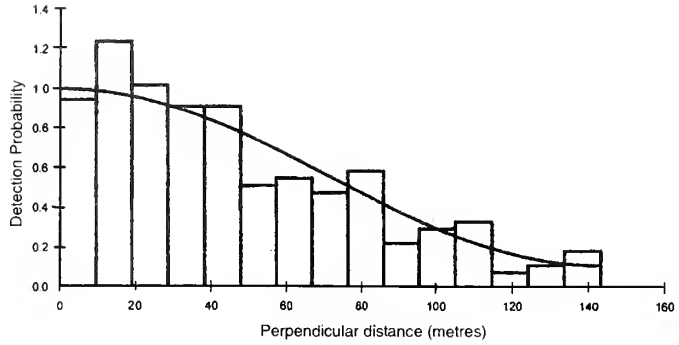

Fig. 1: Detection function model and histogram of sightings of Chital (2003). Uniform key model (KS test D_n = 0.06, p = 0.37)

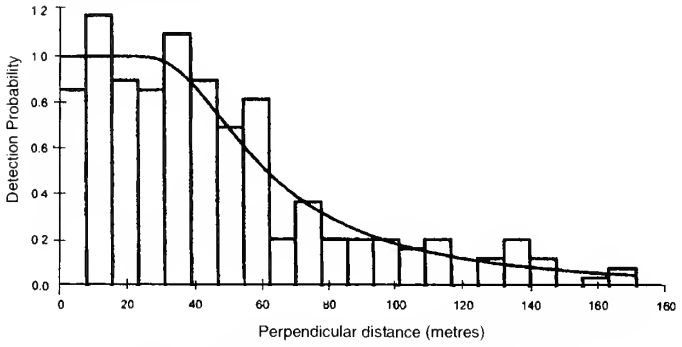

Fig. 2: Detection function model and histogram of sightings of Chital (2001). Hazard rate key model (KS test D_n = 0.03, p = 0.95)

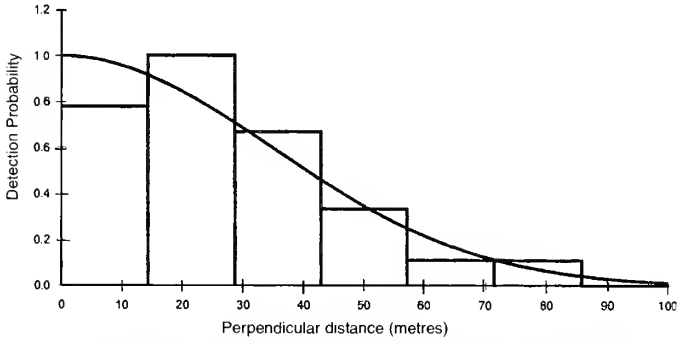

Fig. 3: Detection function model and histogram of sightings of Chital (2000). Half normal key model (KS test D_n = 0.12, p = 0.82)

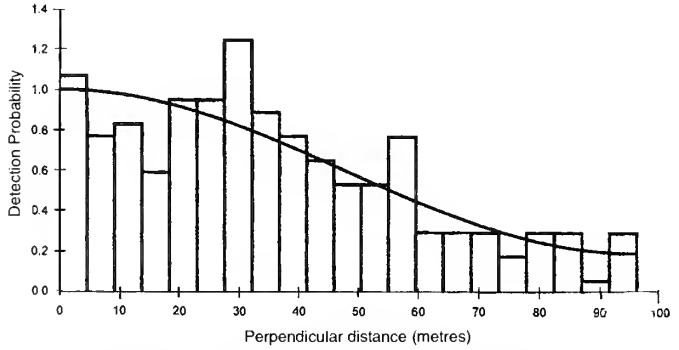

Fig. 4: Detection function model and histogram of sightings of Sambar (2003). Uniform key model (KS test D_n = 0.07, p = 0.23)

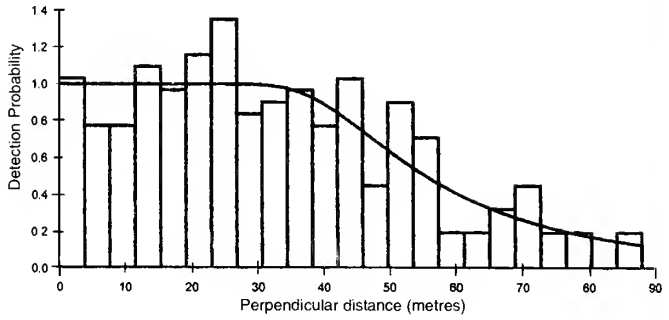

Fig. 5: Detection function model and histogram of sightings of Sambar (2001). Hazard rate key model (KS test D_n = 0.04, p = 0.89)

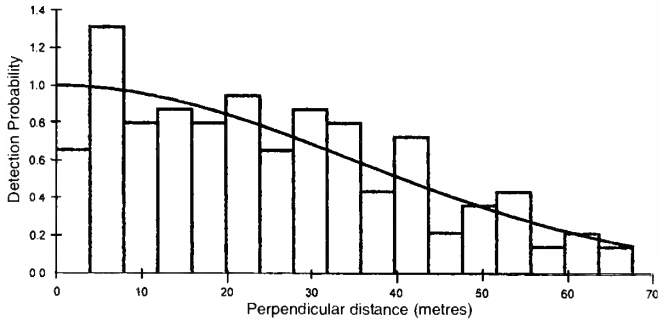

Fig. 6: Detection function model and histogram of sightings of Sambar (2000). Half normal key model (KS test D_n = 0.04, p = 0.99)

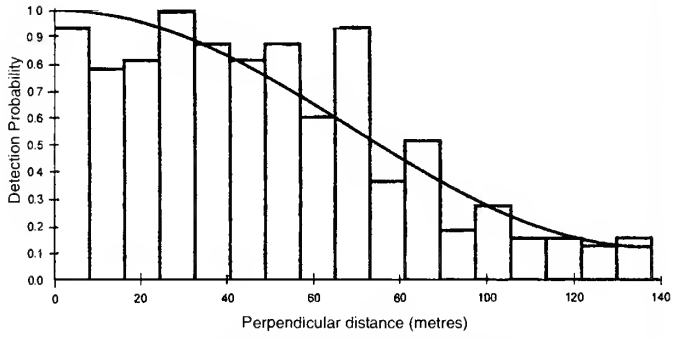

Fig. 7: Detection function model and histogram of sightings of Nilgai (2003). Uniform key model (KS test D_n = 0.05, p = 0.38)

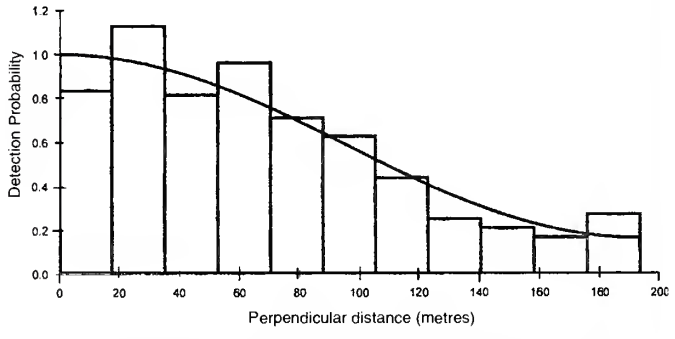

Fig. 8: Detection function model and histogram of sightings of Nilgai (2001). Uniform key model (KS test D_n = 0.06, p = 0.23)

Tiger prey as *n* (clusters seen)/*L* (total length traversed) for comparing the sampling efficiency. Appropriate models were selected from half-normal, uniform key and hazard rate based on minimum Akaike Information Criterion (AIC) values for each year (Figs 1 to 9). Each of the individual species and their respective year's data were used separately to model

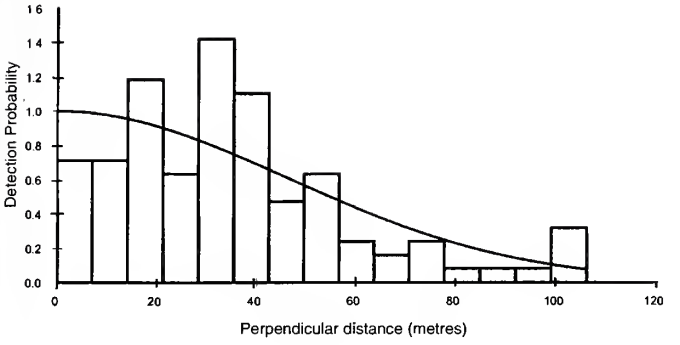

Fig. 9: Detection function model and histogram of sightings of Nilgai (2000). Half-normal key model (KS test D_n = 0.01, p = 0.29)

this detection function. Cluster sizes were estimated using Size-bias Regression method by regressing the natural log of the cluster size against the estimated probability of detection at distance *x*, *g(x)*. The Kolmogorov-Smirnov test was used to test how well our data fitted different models. Histograms were also scrutinised to understand how our data were behaving with respect to the assumptions of the Distance Sampling methodology.

In tropical forests of the subcontinent, ecological conditions change drastically over time and space, and this can affect animal distribution and detection (Thomas *et al.* 2002). After the monsoon (July to October), visibility in forest habitats gradually increases as the long dry season progresses and leaves fall. Loss of foliage makes it easier to detect animals, and they can be sighted from longer distances. In addition to this, changes in group size across seasons is expected to affect the encounter rate of groups of animal. Moreover, during peak summer ungulates congregate near water holes, resulting in a clustered spatial distribution. Therefore, we pooled the 2000 Distance Sampling data bi-monthly to estimate detection functions for each group separately. Changes in encounter rates, group sizes and sighting distances and their likely effects on density estimates were analysed.

To compare seasonal and morning-evening estimates obtained using distance software, one factor ANOVA was used with the available estimates and respective standard deviations (Zar 1984). The technique is valid for such comparisons since different detection functions are estimated for each group compared, and this makes the estimates independent. Changes in other parameters, such as seasonal group size and detection function were tested using one factor ANOVA. Separate detection functions for the morning and evening data sets of the 2001, 2003 and 2005 surveys were estimated. Trends were tested with the help of the maximum R^2 value and with Student's t-test for testing the significance of a regression.

RESULTS

Line transect sampling

In the monthly surveys of 2000, the total length walked was 233.6 km, and 339 animal groups were sighted. In the 2001, 2003 and 2005 surveys, the total length walked was 520.7, 466.06 and 214 km respectively. The total number of animal groups seen was 1,014 during the 2001 survey, 1,023 in the 2003 survey and 520 in the 2005 survey.

Encounter rates of all the prey species varied significantly between the two-month groups (Chital^{2000}: $F=3.538$, $p<0.05$; Nilgai^{2000}: $F=7.494$, $p<0.001$; Sambar^{2000}: $F=5.049$, $p<0.005$). The encounter rates of most of the prey species of Tigers found in Panna Tiger Reserve reach the highest level during February and March (Fig. 10). We used Multiple Covariate Distance Sampling (MCDS) to incorporate the seasonal changes in the detection function. The data were classified into groups of two months each before analysis and these two-month groups were used as factor covariates at the time of analysis. Density estimates of the ungulates varied significantly between the two-month groups (Chital^{2000}: $F=3.066$, $p<0.05$; Nilgai^{2000}: $F=2.87$, $p<0.05$; Sambar^{2000}: $F=4.031$, $p<0.01$). Assuming that the area sampled is closed for changes in population, one would not expect density to change across seasons. This variation can be attributed to either insufficient spatial sampling or actual changes in the study population, which was unlikely.

Mean group size for most of the species did not change significantly during the 2001 (15 days) and 2003 (45 days) surveys. We used Multiple Covariate Distance Sampling Engine (Thomas *et al.* 2003) to address the varying detection function using time period as the covariate. In 2001 and 2003 temporal variation in the detection function was primarily due to fire on the transect lines towards the end of both the surveys. After the fires, visibility increased and could have been responsible for the changes observed. Encounter rates changed significantly only in the case of Nilgai, in the 2003 survey, and show a gradual increase from 0.6 to 0.9 per km ($p<0.01$).

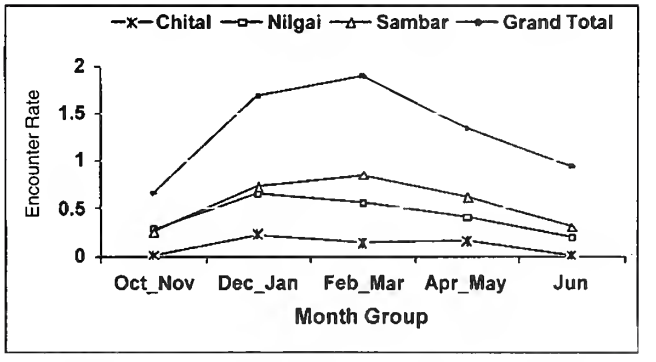

Fig. 10: Bi-monthly (pooled) encounter rates of major prey species of Tiger during the 2000 survey in Panna Tiger Reserve

During the surveys of 2001 and 2003, the encounter rates for most species differed significantly from morning to evening (Sambar^{2003}: F=5.59, p=0.05; Nilgai^{2003}: F=11.35, p=0.005; Sambar^{2001}: F=9.24, p=0.01), and these rates were consistently lower in the evening for all the species. Despite calculating separate detection functions for morning and evening, a significant difference in density estimates is observed for Sambar and Nilgai in 2001 and 2003 (one-tailed tests Nilgai^{2003}: F = 16.63, p=0.001; Sambar^{2001}: F=11.03, p=0.005). A difference in density estimates indicates a bias associated with the distribution of animals with respect to the transect. In 2003, the same transect lines were walked in the morning and evening every fourth day to examine the effect of disturbance from repeated walking, but the results were similar to those of 2001, showing consistently lower encounter rates (and hence density estimates) in the evening. Unlike previous surveys of 2001 and 2003, in 2005 the same transect line was not walked twice on the same day (morning and evening); instead these were walked for the second time after a gap of over two days. The group size, encounter rate and other parameters such as the detection function did not vary between morning and evening counts of the 2005 survey. As a result no significant difference is observed in the densities estimated from morning and evening counts of Tiger prey in the 2005 surveys (Table 1).

Encounter rates for all the species, except Sambar, gradually declined with the length of time spent in walking the transect length in both the morning and evening surveys. In the case of Chital, there was a significant negative trend in the morning surveys (R^2_{2001}=0.73, t_{2001}=3.28, p=0.05; R^2_{2003}=0.76; t_{2003}=4.33, p=0.005) and evening surveys (R^2_{2001}=0.88, t_{2001}=5.43, p=0.01; R^2_{2003}=0.88, t_{2003}=6.53, p=0.001) of both years. Similarly, for Nilgai, the results show a significant declining trend in the morning surveys of 2003 (R^2_{2001}=0.48, t_{2001}=1.91, p=0.2; R^2_{2003}=0.58, t_{2003}=2.87, p=0.05) and in the evening surveys of 2001 (R^2_{2001}=0.93, t=7.18, p=0.002; R^2_{2003}=0.26, t=1.47, p=0.2). However, although the Sambar encounter rate declined in the morning, it increased marginally close to dusk (Fig. 11).

Density and Biomass estimation

The pooled prey abundance is estimated to be 46.32 prey per sq. km, (excluding Langur, 2003 survey). Details of the estimated prey densities and other relevant parameters are provided in Table 2. As in many of the Tiger habitats of the Subcontinent, Chital, Sambar and Nilgai dominate the wild prey population in Panna Tiger Reserve. In terms of number of animals per square kilometre, Chital is the most abundant animal. In the Reserve, the contribution of smaller prey in terms of number of animals (<25 kg and including Langur) is 30%, that of medium sized prey (25 kg to <55 kg), which includes Chital and Wild Pig, is 38% and that of large prey (>55 kg), which includes Sambar and Nilgai, is 31%. The most frequently encountered prey in the Reserve is Nilgai (Encounter rate=0.68 per km) followed by Chital (Encounter rate=0.49 per km) and Sambar (encounter rate=0.45 per km).

The ungulate prey biomass density estimated from the 2003 survey for Panna Tiger Reserve (4,057 kg per sq. km) is on the higher side for the Subcontinent. But most of the biomass (over 70%) is contributed by two prey species, Nilgai and Sambar. The contribution of Chital, the Tiger's most common and major prey throughout the Subcontinent, is only 19.69%. The contribution from other smaller prey species is less than 7%.

DISCUSSION

Due to the prevailing phenological conditions in the tropical dry forests, the encounter rate and detection function are expected to vary seasonally. The changes observed in density estimates despite applying different detection functions for each two-month group indicate insufficient sampling of the study area. We were limited to use MCDS (Buckland *et al.* 2004) because not only the detection function, but their shapes were also changing. Therefore, pooling data from surveys conducted across seasons in changing ecological circumstances may not be a reliable way to estimate densities in a tropical dry forest.

Table 1: Comparison of morning and evening density estimates of three major Tiger preys calculated from the 2005 survey in Panna Tiger Reserve

	Chital		Sambar		Nilgai	
	Morning	Evening	Morning	Evening	Morning	Evening
Density	28.33	29.61	12.51	10.77	11.27	8.80
SE	12.68	16.87	4.48	4.40	3.11	2.80
n	11	9	11	9	11	9
F	0.04		0.76		3.42	
p	0.84**		0.39**		0.08**	

**= no significance

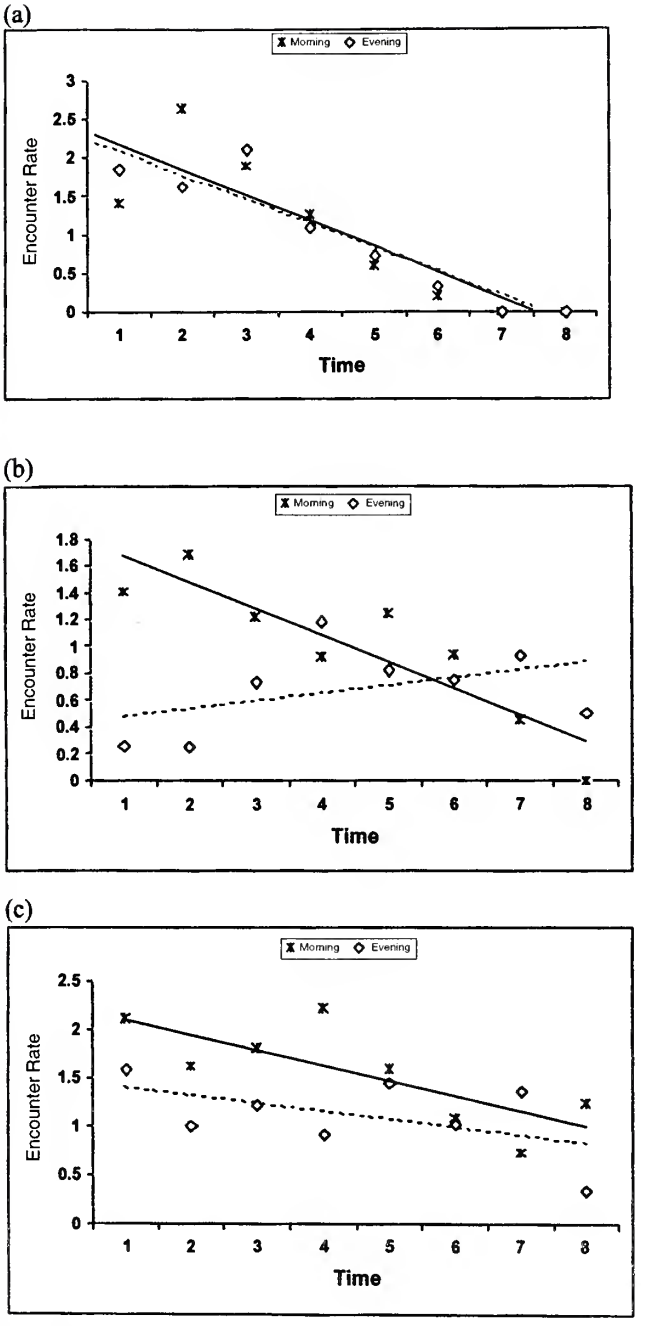

Fig. 11: Encounter rates (groups per hour) pooled for every 15 minutes time interval of three species in the morning (between 0645-0830 hrs) and evening (between 1630-1815 hrs), in Panna Tiger Reserve. Dotted line: trend for evening; continuous line: trend for morning. (a) Chital; (b) Sambar and (c) Nilgai

The highest encounter rates for most ungulate prey were obtained during February and March. During these months the group sizes were also close to the mean estimated for the year; moreover, the prey population was not clustered. Therefore, for estimation of wild herbivore populations in a tropical dry forest, February/March appears to be the most suitable time. Walking several transect lines simultaneously and repeatedly every morning and evening maximised the number of detections for the effort (Karanth *et al.* 2002). The error associated with varying encounter rates, change in group sizes and effect of visibility on radial distance and ESW is minimised effectively when the surveys are conducted within a short time span (ranging from 15 to 40 days). Our data suffers from high CVs for a few species, which could be accredited to the small number of lines. However, an estimation of the number of lines required to bring down this CV to a reasonable range of about 20-25% gives an unfeasible number of more than 60 lines. Since the animal distribution is greatly influenced by the various habitat types in the study area, a more logical approach would be to have more lines and stratify the study area on the basis of habitats.

Disturbance from repeated walks on a line in the same day may be enough to cause animals to move away from the area resulting in consistently low density estimates for evening counts. The 2005 experimental survey results show no difference in the density estimates of morning and evening when the line is walked two days after the previous walk. This confirms that disturbance caused by repeated walking on the line was resulting in lower estimates for the evening count of the same day in other surveys. As a result, density estimates from walks repeated on the same day may be under-estimating prey populations of the area.

The activity pattern of prey species during the sampling period can be another factor which can affect density estimates. It is generally assumed that most of the animals are active in the morning and evening (Karanth and Sunquist 1992). This is a factor likely to affect sighting of animal groups and density estimates. The survey results highlight an additional point that counting animals for more than 2 hours can affect the density estimate because of the shift in animal activity patterns within a single walk. Hence, it is important to incorporate survey time as a covariate in the analysis for transects whenever the activity is expected to change within the survey.

To minimise the error encountered in the morning and evening counts of the 2001 and 2003 surveys, and the variability in group size and encounter rate in the 2000 survey, a new survey design is needed. A sampling period (as short as possible) with more randomly or systematically placed lines, which are walked once a day and repeated after a few days, can possibly minimise the errors.

The density estimate of 46.32 prey per sq. km in Panna Tiger Reserve is fairly high for a tropical dry forest of the Indian subcontinent (Karanth and Sunquist 1992; Khan *et al.* 1996; Biswas and Sanker 2002; Bagchi *et al.* 2003). Because mega-herbivores such as Wild Buffaloes *Bubalus bubalis*,

Table 2: Density estimates and biomass density (kg per sq. km) of Tiger prey in Panna Tiger Reserve obtained from 2000, 2001 and 2003 surveys

Species	Year	N	D	D CV %	95% CL		Encounter Rate	Cluster size	Dg	Dg CV%	Wt in kg	Biomass density
					LCL	UCL						
Chital	2000	27	4.692	62.1	1.232	17.872	0.12	3.48	1.348	60.9	47	220.524
	2001	231	10.953	52.9	3.659	32.784	0.45	3.92	3.096	52.5		514.791
	2003	229	16.671	51.9	5.461	50.899	0.49	6	3.094	51.3		783.537
Sambar	2000	140	18.738	34.9	8.455	41.527	0.6	2.61	7.187	34.2	134	2510.892
	2001	240	8.773	37.2	3.964	19.419	0.47	2.3	3.97	36.9		1175.582
	2003	212	10.355	34.1	4.873	22.004	0.45	2.62	3.955	33.7		1387.57
Nilgai	2000	102	11.374	29.1	6.14	21.069	0.44	3.14	3.625	26	125	1421.75
	2001	307	6.301	37.2	2.836	13.998	0.6	2.72	2.671	37		787.625
	2003	316	13.112	26	7.445	23.091	0.68	2.98	4.403	24.5		1639
Four-horned Antelope	2000	31	2.975	31.9	1.55	5.713	0.13	1.61	1.845	29.5	21	62.475
	2001	106	3.952	19.2	2.621	5.958	0.21	1.23	3.327	19		82.992
	2003	78	2.702	20.6	1.739	4.198	0.17	1.22	2.218	20.2		56.742
Wild Pig	2000	6	*Data set too small to estimate density*				32	NA				
	2001	39	1.367	46.5	0.543	3.441	0.08	3.28	0.584	42.6		27.34
	2003	19	1.511	57.8	0.493	4.627	0.04	4.05	0.373	52.1		30.22
Chinkara	2000	24	2.301	50.3	0.763	6.94	0.1	1.88	1.227	49.4	20	73.632
	2001	52	0.913	42.1	0.381	2.188	0.1	1.62	0.723	41.6		29.216
	2003	81	1.979	45.5	0.735	5.324	0.17	1.81	1.09	45.1		63.328
Langur	2000	40	25.314	37.8	10.94	58.574	0.17	11.23	2.255	36.4	9	227.826
	2001	142	20.689	26.7	11.756	36.412	0.28	8.22	2.517	25.6		186.201
	2003	62	13.909	0.189	9.476	20.417	0.13	11.55	1.204	16.6		125.181

N = number of detection; D = density of animals per sq. km; DCV = coefficient of variation density; 95% CL = 95% confidence interval; Dg = group density per sq. km; Dg CV = coefficient of variation of group density; Wt in kg = average weight of the species; LCL = lower confidence limit; UCL = upper confidence limit

Rhinos *Rhinoceros unicornis* and Elephants *Elaphus maximus*, which contribute very little to the diet of the Tiger, are absent from a large part of the tropical dry forest, they are excluded for comparison of the prey populations (Table 3) based on this study, and Karanth and Nichols (2000). Biomass densities from these other Tiger habitats indicate that, on average, medium sized prey (46.64%) and large prey (52.27%) contribute almost equally to the prey availability. Interestingly, in terms of number of animals, medium sized prey, such as Chital, Wild Pig and Hog Deer contribute, on average, over 70% of prey availability (Table 3). In contrast to this, in Panna Tiger Reserve, the contribution by Chital and other medium prey to the prey population is small, both in term of biomass density (21.26%) and the number of animals (39.24%).

The low abundance of Chital, one of the Tiger's major preys, could be an important factor in the Tiger ecology in Panna. Being the only grazing wild herbivore (Eisenberg and Seidensticker 1976; Putman 1988; Khan *et al.* 1996), the Chital is particularly and highly susceptible to the grazing pressure of domestic livestock populations (Khan 1996; Jathanna *et al.* 2003). A large population of over 9,000 domestic cattle within Panna Tiger Reserve and extensive accidental fires in the past could be the factors limiting the Chital population here. Chital prefer grasses despite their low nutritive value even during the dry summer months (Khan *et al.* 1996). Dry season fires are devastating in Panna, completely eradicating grasses from the burnt areas. In the recent past, rehabilitation of three villages and intensive fire

Table 3: Biomass density (kg per sq. km) and density (animals per sq. km) of medium and large Tiger prey in different Protected Areas of the Indian subcontinent, (Large prey = Sambar, Swamp Deer, Nilgai; medium prey = Chital, Hog Deer, Wild Pig)

Important tiger habitat	Biomass Density (%)		Animal density, medium prey
	Large prey	Medium prey	
Pench NP[1]	41.08	58.91	81.66
Kanha NP[1]	18.76	80.81	91.09
Kaziranga NP[1]	69.85	30.14	70.91
Nagarahole NP[1]	56.13	44.13	73.91
Ranthambhore NP[1]	54.76	44.59	69.3
Panna NP[2]	73.08	21.26	39.24
Average	52.27	46.64	71.02

[1]Karanth and Nichols 2000; [2]This year

protection measures have created extensive grasslands and restored them as suitable habitats for Chital. As a result the Chital population is recovering, mainly in areas recently made free from human pressure, as has been documented in other protected forests of the Subcontinent (Karanth and Sunquist 1992; Khan *et al.* 1996).

The Tropical Dry Forest of Panna supports ungulate populations that have evolved in different environments, one in open habitats, and the other in forest mosaics. Nilgai and Chinkara represent prey populations partial to open habitats whereas Sambar and Chital are forest and forest-edge dwellers (Schaller 1967; Prater 1988; Eisenberg and Seidensticker 1977). Because the Tiger has evolved as a specialised forest-edge predator following the cervid radiation in Asia (Sunquist *et al.* 1999), its survival and hunting strategies are more cued to cervids than other prey species that occupy the open habitats, such as Nilgai. Therefore, in dry forests, a high abundance of prey in open habitats (such as Nilgai) does not entirely translate into Tiger prey availability. Thus, an appropriate balance of prey species needs to be maintained in order to support healthy Tiger populations. Density estimates of Tiger prey from Pench, Ranthambhore, Gir and Panna indicate that tropical dry forests — the largest Tiger habitat in India (Wikramanayake *et al.* 1998) — can support a fairly high prey biomass, provided the habitat is adequately protected.

ACKNOWLEDGEMENTS

The work presented in this paper was supported by Global Tiger Patrol, National Fish and Wildlife Foundation and Wildlife Conservation Society. We would especially like to thank the State Forest Department of Madhya Pradesh for permission to conduct the study in Panna National Park. We are grateful to Dr. Ullas Karanth, Shri Samba Kumar and other volunteers from Centre for Wildlife Studies for their help and assistance in the field exercise in 2002. We deeply appreciate the field work done by the project staff and are grateful for their dedicated assistance throughout the study. We are highly thankful to Ajith Kumar, James Nichols and Len Thomas for their constructive comments on the draft, and to Joanna Van Gruisen for her editorial assistance and review.

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QUANTIFICATION OF THREATS AND SUGGESTED AMELIORATIVE MEASURES FOR THE CONSERVATION OF THE CRITICALLY ENDANGERED JERDON'S COURSER *RHINOPTILUS BITORQUATUS* AND ITS HABITAT

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Jerdon's Courser *Rhinoptilus bitorquatus* is a nocturnally active cursorial bird that is only known to occur in a small area of scrub jungle in and around Sri Lankamaleswara Wildlife Sanctuary, Cuddapah district, Andhra Pradesh, India, and is listed as Critically Endangered by the IUCN. Jerdon's Courser prefers a specific type of scrub jungle with open areas, and there is considerable pressure from human use of apparently suitable habitats. Although major threats to the survival of the Jerdon's Courser have been indentified, there is no quantitative information available. During our study, nine specific threats were identified to the survival of the Jerdon's Courser and its habitat. Habitat destruction and alteration is the major threat among them. However, the immediate threat for the only known population of the Jerdon's Courser in the world and its habitat is the construction of the Telugu-Ganga Canal near Sri Lankamaleswara Wildlife Sanctuary and Sri Penusula Narasimha Wildlife Sanctuary. The presence of the Jerdon's Courser was detected in three new locations in and around the Sri Lankamaleswara Wildlife Sanctuary, and one of these sites was destroyed due to the canal construction. There is an urgent need to save the scrub jungle habitat in and around the sanctuaries. We suggest several ameliorative measures for the conservation of the Jerdon's Courser and its habitat.

Key words: Jerdon's Courser, *Rhinoptilus bitorquatus*, conservation issues

INTRODUCTION

Jerdon's Courser *Rhinoptilus bitorquatus* is a nocturnal cursorial bird which is categorised as Critically Endangered in the IUCN Red List (BirdLife International 2001) since it is believed to have a single, small, declining population. It is listed under Schedule I of the Indian Wildlife (Protection) Act 1972 and is considered as a priority species under the National Wildlife Action Plan (2002-2016) of the Government of India (Government of India 2002). Although reported from other sites in the 1980s (Bhushan 1990), since that time it has only been reported from the small patch of scrub jungle in and around Sri Lankamaleswara Wildlife Sanctuary, Cuddapah district, Andhra Pradesh, India. Exploitation of scrub jungle habitat, livestock grazing and quarrying are the major threats identified so far to the Jerdon's Courser (Birdlife International 2001). Bhushan (1990) stated that major threat for the Jerdon's Courser and its habitat was the collection of minor forest produce such as fuel wood and timber by the local villagers in and around the Sri Lankamaleswara Wildlife Sanctuary. However, there is no comprehensive study to identify and to quantify the specific threats to this critically endangered bird and its habitat. In this paper we have discussed the recent threats faced by the Jerdon's Courser and its habitat.

STUDY AREA

This study was conducted from September 2000 to December 2005 in scrub jungle in the Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries, in Cuddapah district, Andhra Pradesh (Fig. 1). The forest type in the main study area is defined as southern tropical thorn scrub (Champion and Seth 1968). The major vegetation in the scrub forest consists of *Acacia* spp., *Ziziphus rugosa* and *Carissa carandas*, and the major tree species are *Hardwickia binata* and *Anogeissus latifolia*. The scrub jungle is bordered by dry mixed deciduous and Red Sanders-bearing forest consisting of *Pterocarpus santalinus, Terminalia chebula* and *T. tomentosa.* There are patches of dry savannah forest consisting of *Anogeissus latifolia* and *Phyllanthus emblica.* Generally hot weather prevails throughout the year in the study area. Records for Cuddapah from 2001 to 2004 show that the mean monthly daytime temperature ranges between 17.1 °C in December and 42 °C in May. Cuddapah is one of the drought-prone districts of Andhra Pradesh, and the average rainfall for 50 years (1901-1950) was 744 mm (Jagannadha Sarma 2002).

Sri Lankamaleswara Wildlife Sanctuary

A major part of the study was carried out in and around

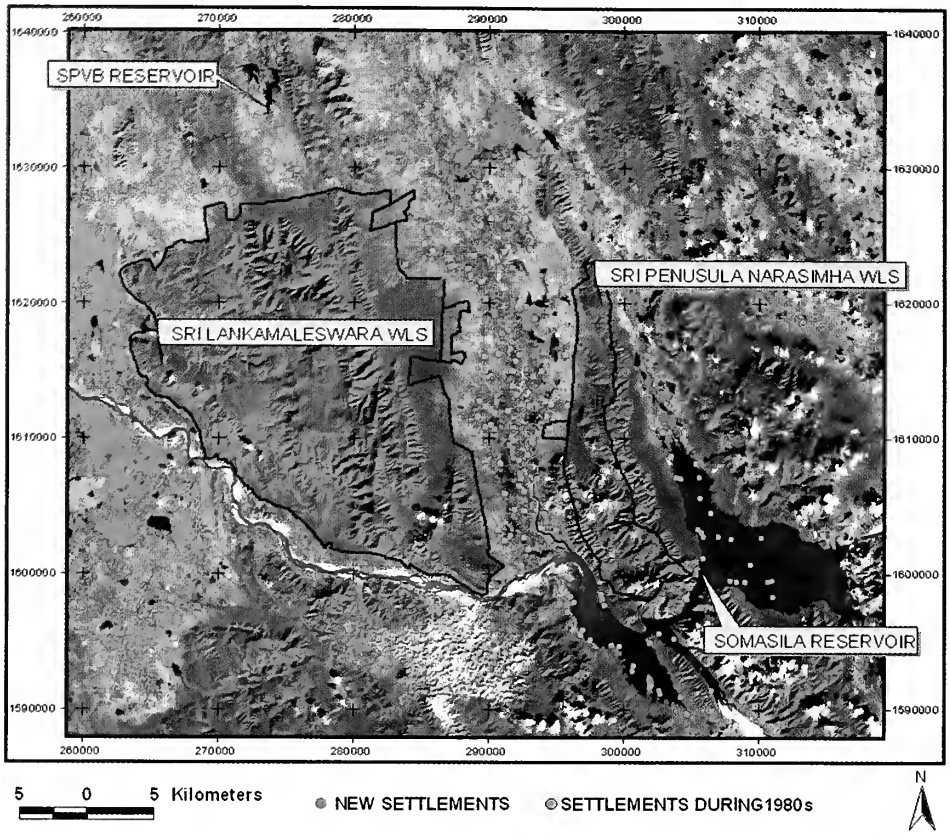

Fig. 1: Settlements near the Sri Lankamaleswara and Cuddapah Division of Sri Penusula Narasimha Wildlife sanctuaries Yellow dots: old settlements (during 1980s) are taken from Survey of India toposheets, and red dots: new settlements (formed within 10-15 years) mapped during this study. Map overlaid on Landsat 7 ETM satellite image (path/row 143/050) of December 06, 2000. (Co-ordinates are in UTM)

the Sri Lankamaleswara Wildlife Sanctuary (SLWLS), Cuddapah district, Andhra Pradesh, India. Geographically, SLWLS lies between the Nallamalais and the Sechachalam hill ranges in the central part of the Eastern Ghats. SLWLS extends over 464 sq. km and is located between 14°45'-14°72' N and 79°07'-78°80' E. The Sanctuary ranges from about 137 m to 784 m above mean sea level in elevation (Fig. 1). The study area was bordered in the west by dense scrub and dry Red Sanders-bearing forest as well as southern dry mixed deciduous forests on the higher elevations of the Lankamalai Hills. To the east, agricultural fields, orchards and croplands are found in the valleys of the semi-perennial Sagileru river. Sagileru joins the Pennar river, which borders the southern part as well as a part of the western side of the Sanctuary (Fig. 1).

Sri Penusula Narasimha Wildlife Sanctuary

Sri Penusula Narasimha Wildlife Sanctuary (SPNWLS) spreads across the districts of Cuddapah and Nellore, Andhra Pradesh (14°18'-14°41' N; 79°05'-79° 37' E). SPNWLS is adjacent to the SLWLS region and covers 1,031 sq. km (Fig. 1). This area encompasses the Turupukonda Hills, part of the Velikonda hill ranges, Somasila dam and Kandaleru reservoir. SPNWLS is separated from SLWLS by the River Sagileru. This study was conducted mainly on the western slope of the Turupukonda Hills for about 6 months in the scrub jungle habitat. This place is accessible from the eastern part of the SLWLS and falls within Cuddapah district. The climate of SPNWLS is similar to that of the SLWLS region. The vegetation and forest types do not differ much from those of SLWLS at least in the western part this Sanctuary. Moist deciduous forest and dry thorn forest are present at the foothills of the Velikonda hill ranges.

METHODS

Disturbance of the scrub jungle habitat from anthropogenic activities such as livestock grazing were documented near the Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries from 2000 to 2005. The

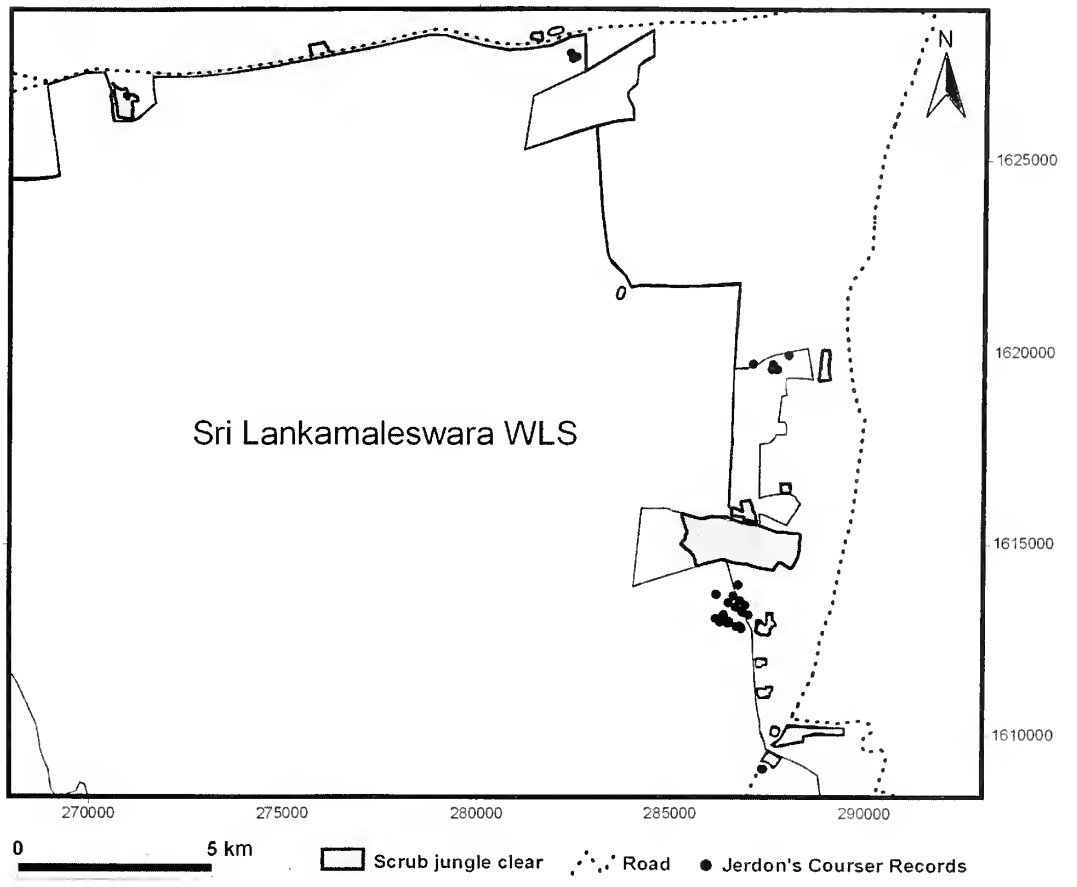

Fig. 2: Scrub jungle clearance and Jerdon's Courser records in and around Sri Lankamaleswara Wildlife Sanctuary (Co-ordinates are in UTM)

presence of Jerdon's Coursers was detected by playing tape recordings to elicit calls (Jeganathan and Wotton 2004) and following the tracking strip method (Jeganathan *et al.* 2002). Tracking strips were placed in the eastern part of Sri Lankamaleswara Wildlife Sanctuary and in the western part of the Turupukonda forest, which is situated in the Cuddapah part of the Sri Penusula Narasimha Wildlife Sanctuary, and on the western side of the Velikonda hill ranges. Tree and bush species were counted and identified, and the substrates and ground vegetation described within 10 x 10 m plots at the locations of tracking strips. By relating the rate of tracking of the Jerdon's Courser to these habitat traits, the preferred habitat of the Jerdon's Courser was identified as scrub jungle with open areas where the density of large bushes (> 2 m tall) is in the range 300 - 700 per ha and the density of small bushes is < 1,000 per ha (Jeganathan *et al.* 2004).

Scrub jungle with open areas, which are potentially suitable habitat of the Jerdon's Courser were cleared and developmental activities took place in and around the Sanctuary areas during the study period. The Telugu-Ganga Canal was constructed in and near the Sanctuary areas during October 2005. All anthropogenic activities were recorded, and the places where such activities occurred were marked using a GPS. The potentially suitable habitat of the Jerdon's Courser was mapped with the help of satellite imagery (Jeganathan *et al.* 2005). The extent of the area cleared was mapped by walking along the edge with a GPS. A map of the cleared areas was kept as an overlay on the potentially suitable habitat of the Jerdon's Courser to find out the extent of the habitat loss. This was achieved with the help of ERDAS imagine 8.5 and Arc View GIS 3.2a software.

Instances of livestock grazing were established using the footprints of goats, sheep and buffalo on tracking strips and the rate of tracking was calculated. The number of households and the cattle population were determined in November 2005 by interviewing locals from the 14 villages around the northern and eastern boundaries of the Sri Lankamaleswara Wildlife Sanctuary.

The amount of wood cut was quantified by noting the scrub and tree species cut in the 10 m square habitat recording plots. Totally 294 plots were surveyed in and near the Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries, as well as in the reserved forest areas of the Velikonda foothills. Apart from this, the extent of human use

of these forest areas was quantified by calculating the rate of encountering head loads, cart loads and tractor loads of timber and non-timber forest produce (NTFP).

Threats to the Jerdon's Courser Habitat

Previously the presence of the Jerdon's Courser was only confirmed inside and near Sri Lankamaleswara Wildlife Sanctuary (Bhushan 1986). Through the tracking strip and tape playback survey it was detected in three new places.

Nine specific threats were identified to the survival of the Jerdon's Courser and its habitat. Habitat destruction and alteration is the major threat among them. However, the immediate threat to the only known world population of the Jerdon's Courser is the construction of the Telugu-Ganga Canal near the two sanctuaries.

1. Scrub jungle clearance for farming and plantation

An area of about 480 ha of the scrub jungle was cleared during the study period (2001-2004) in and around the Sri Lankamaleswara Wildlife Sanctuary. Of this, nearly 275 ha of the scrub jungle, which is potentially suitable for the Jerdon's Courser, was cleared to provide land for agriculture to people who were displaced by floods, and for lemon farming and forestry plantations. These cleared places fall within about 1 km from the previously known and newly detected Jerdon's Courser areas (Fig. 2). Scrub jungle habitat was cleared inside the Sri Lankamaleswara Wildlife Sanctuary mainly for raising forestry plantations consisting of *Pongamia pinnata, Terminalia arjuna, Cassia siamea, Eucalyptus* sp. and *Syzygium cumini.* Analysis of Landsat satellite imagery showed that the clearance of scrub jungle in this region has been happening before the beginning of our field study in 2000. Analysis of satellite images show that between 1991 and 2000 11-15% of the scrub jungle has been cleared, especially close to human settlements (Senapathi *et al.* 2007).

2. Developmental activities inside the Sri Lankamaleswara Wildlife Sanctuary

Apart from the plantations, several other developmental activities such as the construction of check dams and digging of percolation ponds and trenches were noticed during the study period. It should be noted that trenches were dug in the places where the Jerdon's Courser has been seen regularly since its rediscovery in 1986. The trenches stretch over different lengths from 50 m to 1.3 km; they are 2 m deep, and the width varies from 2 to 5 m. The trenches were dug at intervals of 20 to 50 m. Five percolation ponds were constructed near the main Jerdon's Courser area during the study period. About 0.5 to 1 ha of scrub jungle was cleared for each pond and an earthen bund was constructed by piling up the soil dug for the pond. On the bund, exotic plant species were planted. Apart from this, in the scrub jungle habitat another type of forestry practice called thinning and singling was noted in which all the scrub species were cleared except the saplings (1-2 m in height) of tree species such as *Hardwickia binata, Anogeissus latifolia, Manilkara hexandra* and *Soymida febrifuga.* Later, circular pits were dug around these trees, which facilitates collection of rain water. Also, several small pits were dug for rain water collection in the cleared open areas where this thinning was carried out.

3. Quarrying in and around Sri Lankamaleswara Wildlife Sanctuary

Stones of different sizes present on the ground were collected for road construction every year from the scrub jungle habitat both in and outside Sri Lankamaleswara Wildlife Sanctuary. Apart from this, bigger stones below the ground were dug up using crowbars and broken into pieces and collected in heavy vehicles. These stones were collected for house construction by the nearby villagers. Large pits were dug up in about 15 places in and outside the eastern part of Sri Lankamaleswara Wildlife Sanctuary. However, no instance of using explosives for quarrying was noted during the study period.

4. Increasing number of settlements near the sanctuaries

Bhushan (1995) reports that the construction of the Somasila dam resulted in the displacement of 57 villages, which moved closer to Sri Lankamaleswara Wildlife Sanctuary. The construction of the Somasila dam was completed in 1989 (Nikku 2004). The locations of the villages near the study area were obtained from Survey of India toposheets, which were based on surveys conducted in 1986 prior to the construction of the Somasila dam. GPS locations of villages near Sri Lankamaleswara Wildlife Sanctuary were taken. These locations were plotted, and a map was produced. Village locations taken from the toposheets plotted on the Landsat ETM Satellite image of December 06, 2000 shows that nearly 45 villages were submerged under the Somasila reservoir (Fig. 1). There are about 146 villages present between the eastern part of Sri Lankamaleswara Wildlife Sanctuary and the western side of the Cuddapah Division of Sri Penusula Narasimha Wildlife Sanctuary. Of these 146 villages, 25 were formed in recent times (within 10 to 15 years). This was established by interviewing the local people from these villages. It should be noted that most of these villagers moved from the bank of the Sagileru river, which runs in-between Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries. It was observed during the

study period (from 2000 to 2005) that Sagileru river was flooded three times in the rainy season. Villagers near the bank of the Sagileru river moved towards the west, near the Badvel-Siddavatam road, which is about 2 km away from the eastern boundary of Sri Lankamaleswara Wildlife Sanctuary.

Besides this, about 15 villages were displaced due to the construction of Sri Potuluri Veera Brahmendraswamy (SPVB) Reservoir in the place called Bramhamgarimatam, which is about 12 km north of Sri Lankamaleswara Wildlife Sanctuary (Fig. 1). Twelve villages are present within 1 km from the northern boundary of Sri Lankamaleswara Wildlife Sanctuary, of which seven villages were resettled due to the construction of the SPVB reservoir near the Badvel-Mydukur, which partly forms the northern boundary of this Sanctuary.

It should be noted that there are even more villages in the flood-prone area of the Somasila and SPVB reservoirs which are likely to be resettled near the sanctuaries in the future. Also, there are plans to increase the height of the Somasila dam, which will result in the displacement of more villages to areas near the south-eastern part of Sri Lankamaleswara Wildlife Sanctuary.

5. Agricultural transformation

The major crops around Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries are Paddy *Oryza sativa*, Sunflower *Helianthus annuus*, Cotton *Gossypium* sp., Groundnut *Arachis hypogaea*, Finger Millet *Eleusine coracana*, Turmeric *Curcuma longa* and Onion *Allium cepa*. However, in recent times, several agricultural fields have been transformed into Lemon farms. Species such as Lemon *Citrus limon*, Bitter Lime *Citrus aurantium*, Sweet lime *Citrus sinensis* and Key Lime *Citrus aurantifolia* are grown since they need relatively little water and maintenance, and are lucrative. This agricultural transformation, from dry irrigated crops to lemon farms, was mainly due to erratic and failed seasonal rains. Lemon farms present near the eastern part of Sri Lankamaleswara Wildlife Sanctuary were mapped in June 2004. Farms extend to about 1.5 km on either side of the Badvel-Siddavatam road. The extent of the lemon farms in this region was calculated to be 198 ha. It should be noted that about 215 ha of scrub jungle habitat was cleared outside the Sanctuary from 2000 to 2005 (Fig. 2). Most of these clearance were not yet cultivated and are most likely to be converted into lemon farms in future.

6. Livestock grazing

Three types of livestock grazing were observed in and around Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries. In the first type, shepherds brought their goats, sheep and buffalo regularly every morning from the villages into the scrub jungle habitat in and around the sanctuaries. The animals stray inside the forest for about 2-3 km and return to their villages in the evening. Another type are nomads who possess 200 to 300 cattle. They rear only cows. However, these are not for milk but mainly for the cow dung. They were generally invited by the lemon farm owners to enrich their farms. The graziers stay up to 3 to 4 months in one place before moving to another. All these cattle were seen grazing in the forested areas in and around the sanctuaries. The third type stays with their sheep inside the sanctuaries for grazing throughout the year except during the rainy season. However, this type of grazing was not observed in the scrub jungle habitat.

Tracking strips (a total of 410) were deployed in and around Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries as well as in the reserve forest areas of the Velikonda foothills in 24 blocks. Each block consists of 15-20 tracking strips, usually placed in a regular rectangular or square array. While recording bird footprints in the tracking strips, tracks of goats, sheep and buffalo were also recorded. Footprints of human beings observed in the tracking strips were also recorded. The tracking rate of the cattle and human beings was relatively higher than that of the wild ungulates present in the study area. Goats and sheep tracked were found on 78.5% of the tracking strips. Buffalo and human tracks were recorded in 47% and 72% of the tracking strips, respectively. Details of the tracking events of cattle and humans in the 24 blocks of tracking strips are given in Table 1.

Data on the cattle population and number of households were collected in November 2005 from 14 villages situated in the eastern (10 villages) and northern (four villages) parts of the Sri Lankamaleswara Wildlife Sanctuary. The goat and sheep populations were higher (38% and 36% of the total population, respectively) than that of buffalo (23%). The total number of households recorded in these villages was 1,684. The largest number of households was recorded in Reddipalli (300 households), which is close to the main Jerdon's Courser area. The cattle population exceed 1,000 in three of the villages surveyed (Fig. 3).

7. Use of forest by the villagers

During field visits to the Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries, the removal of timber and non-timber forest products from the forest area by head loads, cart loads and tractor loads was noted from 2001 to 2003. It should be noted that these observations include encounters with fuel wood, wood collected illegally, grass, bamboo and other non-timber forest produce (NTFP). Most of the NTFP, fuel wood, fodder leaves for cattle and single large timbers (DBH approximately 60 to 80 cm) of

c. 2-3 m length were carried by head loads whereas large quantities of timber, fodder leaves and grass were carried either by bullock cart or by tractor. Such events were noted only if they were seen on the forest roads. Although several hundred visits were made to the field, these events were studied only during 256 visits (Table 2). It should be noted that the data collection was not very systematic, as only opportunistic data was collected. Of the 256 visits, these events were encountered on 65% of the total visits. The mean encounter rate of head loads was highest (0.49 ±0.06 per visit), followed by cart loads (0.21 ±0.1 per visit) and tractor loads (0.15 ±0.05 per visit) (Fig. 4).

In the scrub jungle habitat, wood cutting was observed regularly. Mainly *Hardwickia binata* was pollarded during summer for thatching above the front door of houses. Also graziers cut and bend the branches of scrub and tree species to facilitate better access for browsing by goats and sheep, inside the scrub jungle. While recording the habitat in a 10 m square plot centred on the tracking strips, on a total of 294 plots surveyed, and cut marks in 28 scrub and tree species were noted. The maximum of cut marks was observed in *Zizyphus rugosa* (39% of the plots surveyed). Only 8% of plots surveyed had no cut marks (Fig. 5).

Table 1: Tracking rates of goats and sheep, buffalo and humans in 24 blocks of tracking strips deployed in and around Sri Lankamaleswara and Sri Penusula Narasimha Wildlife sanctuaries and in the reserved forest areas of Velikonda foothills from 2000-2003

Block	Tracking strip nights	Tracking rates		
		Goats and Sheep	Buffalo	Human
JC1&2	863	0.023	0.001	0.043
P1S	421	0.007	0	0.014
B1	112	0.071	0.009	0.009
B2	238	0.151	0	0.059
B5	458	0.076	0.114	0.020
B3	477	0.042	0.075	0.034
B9	435	0.092	0.177	0.053
B6	231	0.074	0	0.022
B11	555	0.072	0.020	0.016
HS1-16	756	0.050	0.009	0.029
HS17-27	684	0.029	0	0.035
HS28-39	247	0.016	0	0.053
B8	499	0.150	0.130	0.074
B4*	459	0.083	0.087	0.061
B7	460	0.167	0.209	0.061
B13#	462	0.115	0.149	0.082
B14#	454	0.097	0.099	0.066
B10*	387	0.090	0.111	0.041
B12#	484	0.025	0.010	0.039
B15	471	0.110	0	0.021
B18	465	0.110	0.015	0.009
B17	512	0.068	0	0.012
B19	238	0.151	0	0.059
B20	207	0.053	0.068	0.058

8. Bird trapping

Illegal bird trapping by a particular section of people in the peripheral areas of the eastern part of Sri Lankamaleswara Wildlife Sanctuary was noticed on a few occasions only (<5 encounters on several hundred field visits in four years). It should be noted that on one occasion, a bird trapper was seen near the main Jerdon's Courser area. Traps used by these trappers are nooses and nets. They mainly target Grey Francolin *Francolinus pondicerianus* and Quail spp., which commonly occur in this area. Although trapping, exclusively for the Jerdon's Courser was not reported, it is likely that it maybe caught accidentally in the nooses and nets set for other bird species.

9. Telugu-Ganga Canal

At the time of the rediscovery in 1986, the Jerdon's Courser site was under threat from a plan to construct the Telugu-Ganga Canal across it. Officials from the Forest Department and the State Government of Andhra Pradesh recognised the ornithological importance of the area and declared it as Sri Lankamaleswara Wildlife Sanctuary for the Jerdon's Courser, which included the rediscovery site on its eastern fringe. The proposed course of the canal was adjusted to avoid the Sanctuary (Bhushan 1995). Recently canal construction was started for irrigating land in Sagileru valley. The canal construction was noticed during the last week of October 2005 near Sri Lankamaleswara Wildlife Sanctuary. The origin of the canal is from SPVB (Sri Potuluri Veera Brahmendraswamy) Reservoir near Bramhamgarimatam (Fig. 1). This canal comes southwards and ends 2 km away from Nandhipalli near the Badvel-Mydukur road. It is also referred as the Right Canal. Apart from this, one more canal is being excavated southwards to the east of the Sagileru river, and it goes along the western boundary of Sri Penusula Narasimha Wildlife Sanctuary (Fig. 6). This part of the

Table 2: Observation of collection of forest produce from Sri Lankamaleswara and Sri Penusula Narasimha wildlife sanctuaries from 2001 to 2003

Year	Head load	Cartload	Tractor load	*n*
2001	22	9	9	43
2002	81	31	22	158
2003	22	12	6	55
Total	125	52	37	256

n: number of visits

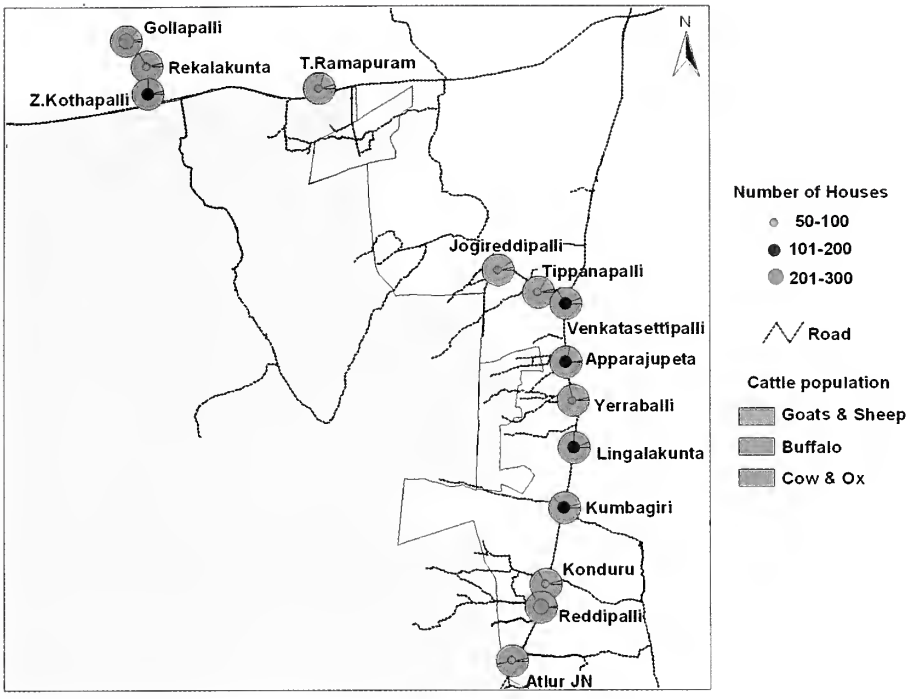

Fig. 3: Number of households and cattle population in 14 villages situated within 2 km from the eastern and northern boundaries of the Sri Lankamaleswara Wildlife Sanctuary. (Map not to scale)

Sanctuary falls under the Cuddapah Forest Division. This canal is referred as the Left Canal. Both the canals were stopped as they were constructed in the forest areas without obtaining prior permission (Jeganathan *et al.* 2005).

The canal route and disturbances noted while constructing the canal, such as new roads to the canal sites and quarrying soil for canal construction in the forest area were documented from November 21 to 28, 2005. The canal was 16 to 20 m wide, but the area cleared for preparing this canal was 80 to 100 m wide. Stones and the soil were dug up and piled all along the canal route. Roads were constructed on either side of the canal using this soil as well as soil dug up from nearby areas.

The canal route was mapped with the help of a GPS by driving the jeep along it and/or walking on it. Tracks of the canal route and other coordinates marked in the field were converted to Arc coverage format. On the screen, simulated lines were drawn on either side of the canal tracks for not less than 40 m to mark the width of the area cleared. This was marked as a polygon and the area was obtained. It should be noted that the area falling inside this polygon has different kinds of habitats such as open ground, rocky terrain and scrub jungle. This coverage was kept as an overlay on a map of potentially suitable habitat of the Jerdon's Courser to find out the habitat loss. Where there was a forest cleared with no canal, it was mapped by walking along the forest

Table 3: Sri Lankamaleswara Wildlife Sanctuary and Cuddapah Division of Sri Penusula Narasimha Wildlife Sanctuary*

Division	Block name	Block code	Compartment numbers
Proddatur	Chennamukkapalle Reserve Forest	19042	76, 77
	Lankamalai Reserve Forest	19043	79, 80, 85, 86, 89, 90, 91, 92, 97, 98
	Lankamalai Reserve Forest	19061	274, 275, 276, 277, 278, 279, 280, 281, 282, 283
	Gopalapuram Reserve Forest	19062	290
Cuddapah	Lankamalai Extension Reserve Forest	19079	376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 392, 394, 395, 396, 399
	Lankamalai Extension Reserve Forest	19080	400
	Lankamalai Reserve Forest	19080	418, 419
	Yerraballi Forest Block	19081	1171
	Turpukonda Extn Reserve Forest*	19077	365, 366, 367, 368, 369,370, 371,374
	Muthukuru Forest Block*	19082	1172

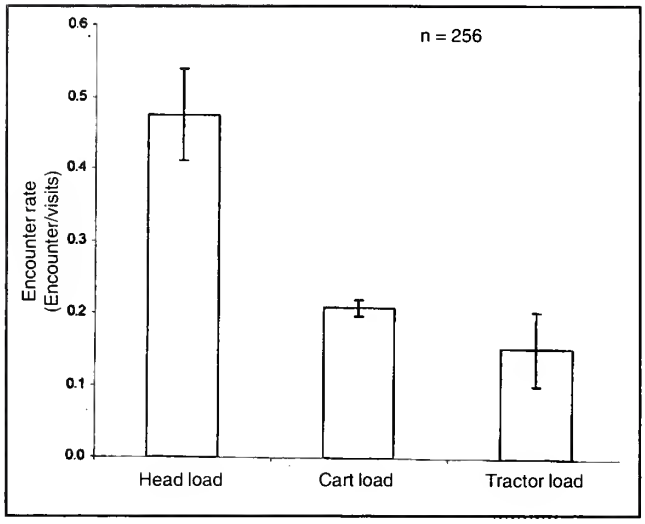

Fig. 4: Mean encounter rate of the observation of collection of forest produce by villagers around Sri Lankamaleswara and Sri Penusula Narasimha Wildlife Sanctuaries from 2001 to 2003

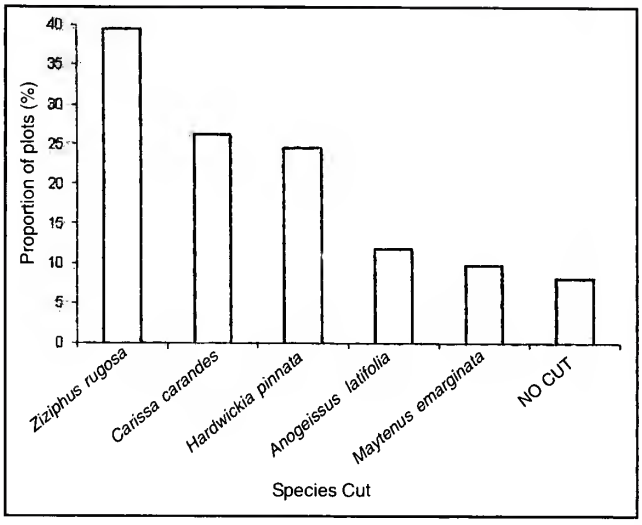

Fig. 5: Cut marks seen in top five scrub and tree species (10% to 40%) of the 294 10-m square plots surveyed. Percentage of plots that do not have any species is also given

clearing. So the width was not simulatend and the track itself was transformed into a polygon and the area was obtained.

The total area cleared estimated for the Right Canal is 114 ha, of which *c.* 22 ha of potentially suitable habitat for the Jerdon's Courser was lost due to the construction of the canal in the eastern part of Sri Lankamaleswara Wildlife Sanctuary. Construction work has also destroyed one of the places where the Jerdon's Courser was recorded in 2001.

The proposed route for the canal construction goes along the Sanctuary boundary and ends at 45 km from its origin near Atlur. Alarmingly, when this canal route reaches its 40th km it goes very close (about 500 m) to the place where the Jerdon's Courser has been sighted regularly from 1986. The scrub jungle in and around this area is the only place where Jerdon's Courser has been sighted frequently, its footprints obtained and its calls heard regularly. This is the only place in the world at the moment where the Jerdon's Courser is known to be present. It was estimated that if excavation for the proposed canal proceeds further, it would destroy *c.* 650 ha of suitable habitat of the Jerdon's Courser around Sri Lankamaleswara Wildlife Sanctuary.

The total area cleared estimated for the construction of the left canal in and around Sri Penusula Narasimha Wildlife Sanctuary is *c.* 163 ha. The forest area cleared is *c.* 8 ha. Further this canal route passes very close to the Sanctuary boundary. A large extent of favourable habitat is present at the foothills of Turupukonda.

DISCUSSION

The Jerdon's Courser uses a specific type of scrub jungle habitat for feeding and breeding. Studies show that the extinction risk of birds increases when habitat loss is severe, especially for habitat specialists (Owens and Bennett 2000; Norris and Harper 2004). The Jerdon's Courser possesses other traits which increase its extinction probability: small geographical range, small population size and occurring at a low elevation (Gaston 1994; Purvis *et al.* 2000; Gage *et al.* 2004).

Settlements near Sri Lankamaleswara Wildlife Sanctuary already pose a severe threat and more settlements in the future would worsen the threat as this would result in clearing of more scrub jungle habitat, increasing the livestock population and grazing, wood cutting and bird trapping. It should be noted that, out of the 14 villages surveyed around Sri Lankamaleswara Wildlife Sanctuary, the largest number of households and the largest livestock population were recorded in Reddipalli, which is near the main Jerdon's Courser area (Fig. 3). Increasing the number of households and the population around the Sanctuary would pave the way to intense use of the scrub jungle habitat.

Highly populated areas, especially in rural India, are likely to have higher livestock populations. The total livestock in Andhra Pradesh has increased from 36.01 million to 48.20 million between 1999 and 2003 showing an overall increase of 33.8 % (Government of India 2005). Increasing the number of settlements near the Sanctuary is likely to bring more livestock in the future as the livelihood of most of the

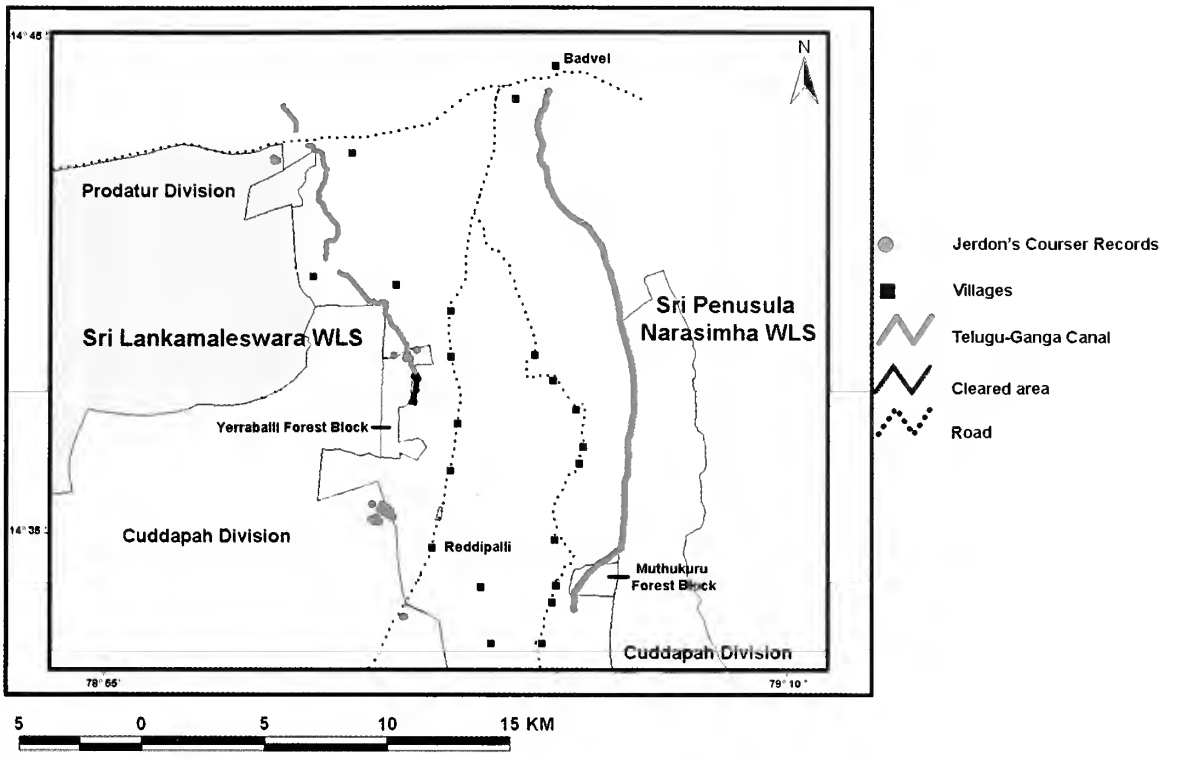

Fig. 6: Route of Telugu-Ganga Canal in and around Sri Lankamaleswara and Sri Penusula Narasimha Wildlife sanctuaries in Cuddapah district, Andhra Pradesh

villagers is cattle rearing, second to agriculture. In rural areas of India, the primary source of energy for cooking is fuel wood. The encounter rate of forest produces carried through head loads was higher compared with cart loads and tractor loads in this study. It should be noted that though the head load category consists of NTFP, grass and illicit wood, the frequency of head loads of fuel wood was greater than that of other forest produce.

Although a moderate amount of grazing and wood cutting would benefit in maintaining the structure of the scrub jungle habitat preferred by the Jerdon's Courser, over-grazing and intense human use would result in deterioration of the habitat.

Although an area covering 43,600 ha was declared as Sri Lankamaleswara Wildlife Sanctuary mainly for the Jerdon's Courser, only *c.* 15% of the land has scrub jungle habitat. Even though the Jerdon's Courser has been recorded at three new places, these are all within 15 km of the original rediscovery site. Most of the anthropogenic activities described above have been witnessed both in and outside the Sanctuary area. Intense human use, over-grazing and increasing number of settlements will surely have a gradual negative impact on the scrub jungle habitat. However, the immediate threat facing the scrub jungle habitat around Sri Lankamaleswara Wildlife Sanctuary is the construction of the Telugu-Ganga Canal. Although the 'Right Canal' has been stopped for the time being, it is estimated that if the canal had been continued, it would have resulted in the loss of *c.* 650 ha of scrub jungle habitat around the Sri Lankamaleswara Wildlife Sanctuary.

The new Telugu-Ganga Canal poses at least three types of threat to the Jerdon's Courser:

(1) Construction will destroy the remaining scrub jungle habitat of the Jerdon's Courser in the eastern part of Sri Lankamaleswara Wildlife Sanctuary. Furthermore, because the population survey work is at an early stage, other Jerdon's Courser sites where the species has not yet been detected will also be destroyed. This will further diminish the population. Absence of Jerdon's Courser records does not imply an absence of the bird, as most of the areas outside the Sanctuary have not been surveyed yet. Therefore, it is imperative to protect the potentially suitable habitat outside the Sanctuary.

(2) The Canal will permit the extension of irrigated agriculture to many areas outside the Sanctuary that are scrub jungle at present. Rapid replacement of forested landscapes by cultivated lands along with a change in cropping pattern has caused deterioration in the Jerdon's Courser's habitat.

(3) Extension of agricultural use will lead to increased human activity in and near the Sanctuary. In turn, this is likely

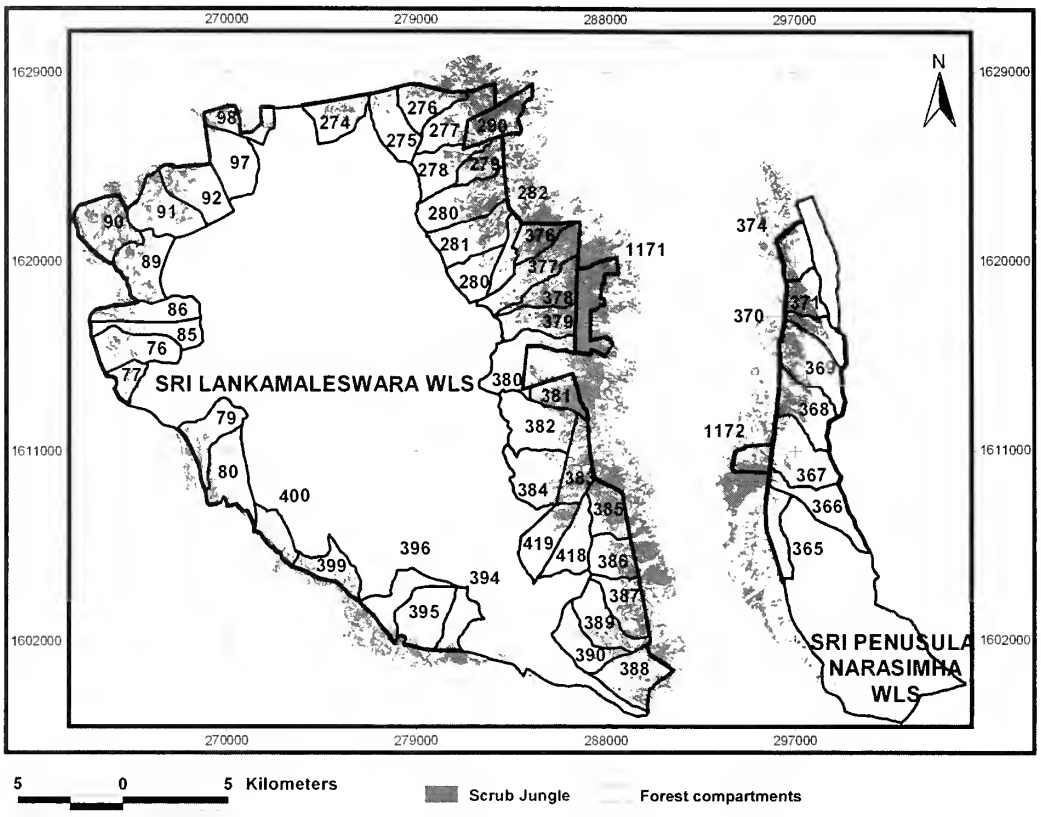

Fig. 7: Distribution of the scrub jungle habitat in and around the Sri Lankamaleswara and Sri Penusula Narasimha Wildlife sanctuaries. Forest compartment numbers in which the scrub jungle occurs are also given. (Co-ordinates are in UTM)

to increase unauthorised human use of the Sanctuary and any remaining scrub jungle outside it. All known Jerdon's Courser sites are already used for grazing of livestock and wood cutting, but at moderate levels, which may help to maintain a suitable vegetation structure for the Jerdon's Courser. However, increased use is likely to reduce the density of bushes below suitable levels for the species. Other unauthorised uses of the Sanctuary include hunting of mammals and bird trapping.

RECOMMENDATIONS

1. The Right Canal should be realigned near Sri Lankamaleswara Wildlife Sanctuary and diverted well away from the potentially suitable habitat of the Jerdon's Courser.

2. Areas west of the proposed Right Canal up to the boundary of the Sanctuary consist of potentially suitable habitat for the Jerdon's Courser. So this entire area should be included in the Sanctuary.

3. In and near the Sri Lankamaleswara Wildlife Sanctuary and Cuddapah Division of Sri Penusula Narasimha Wildlife Sanctuary, the scrub jungle habitat is distributed over nine Forest Blocks (in 55 compartments) as shown in (Fig. 7). Forestry activities such as construction of percolation ponds and trenches, and singling, thinning, and clearing the scrub jungle for planting exotic tree species should not be allowed in the Sanctuary and in blocks with suitable scrub jungle habitat owned by the Forest Department, but currently outside the Sanctuary boundaries. These areas are vital for the survival of the Jerdon's Courser.

4. Over-grazing should be controlled and illegal bird trappers around the Sanctuary should be identified, and measures should be taken to prevent hunting.

5. Before 2000, substantial numbers of foreign birdwatchers came to visit the area to see Jerdon's Coursers. They were guided by a local man and did no harm to the birds. This no longer occurs regularly, resulting in a loss of income from tourism in local villages. The scope for carefully controlled eco-tourism with the possibility of seeing or hearing Jerdon's Courser as the centrepiece should be investigated.

6. A species recovery plan for the protection of the Jerdon's Courser should be prepared based on scientific studies in and around the two sanctuaries and the reserved forests, including detailed plans for all the activities listed above.

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■ ■ ■

NEW DESCRIPTION

DESCRIPTION OF A NEW SPECIES OF THE GENUS *BLACUS* NEES (HYMENOPTERA: BRACONIDAE), ALONG WITH A KEY TO INDIAN SPECIES[1]

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A new species of the genus *Blacus* Nees, namely *Blacus* (*Ganychorus*) *hayati* sp. nov., is described under the subgenus *Ganychorus* from India. A key to the Indian species of *Blacus* is also given.

Key words: Hymenoptera, Braconidae, Blacinae, *Blacus*, new species, India

INTRODUCTION

The genus *Blacus* Nees belongs to the subfamily Blacinae of Braconidae. Achterberg (1988) revised the subfamily and included four species under the genus *Blacus* from India. Recently, Ahmad and Shujauddin (2001) added one species to the genus *Blacus* from India. In the present work, a new species is described and a key to the Indian species of *Blacus* is provided. Achterberg (1988) has been followed for terminologies.

The following abbreviations are used in the text: OOL – ocello-ocular line (distance from the outer edge of a lateral ocellus to the compound eye); POL – post-ocellar line (distance between the inner edges of the two lateral ocelli); AOL – anterior-ocellar line (distance between the inner edges of anterior and lateral ocellus), OD – diameter of an ocellus; ZDAMU–Zoology Department, Aligarh Muslim University.

Key to Indian species of the Genus *Blacus* Nees

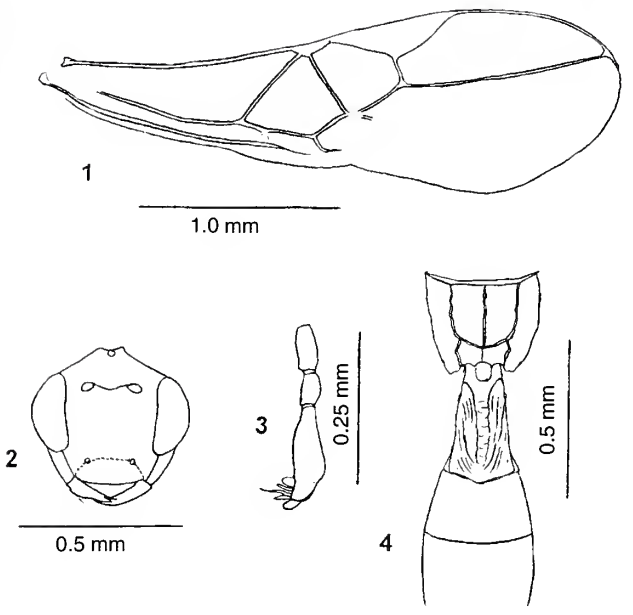
1. Eyes conspicuously setose; medio-posterior propodeal area small and rectangular ..... *Blacus* (*Contochorus*) *turbidus* Papp.
— Eyes glabrous or nearly so; medio-posterior propodeal area different or small 2
2. Propodeal carina comparatively weakly developed; antenna 17 segmented; fore claw of female only setose ..... *Blacus* (*Blacus*) *imitator* Papp.
— Propodeal carina distinctly developed; antennae 20 segmented; fore claw of female with blackish bristles or simple 3
3. Scutellar sulcus smooth; middle tarsal claw of female simple; second metasomal tergite largely costate ..... *Blacus* (*Tarpheion*) *votrus* Papp.
— Scutellar sulcus crenulate; middle tarsal claw of female with blackish bristles; second metasomal tergite smooth 4
4. Fore wing shorter than the body length; ovipositor sheaths approximately 0.2x as long as fore wing; pterostigma uniform ..... *Blacus* (*Ganychorus*) *indicus* Ahmad and Shujauddin
— Fore wing longer than the body length; ovipositor sheaths approximately 0.16x as long as fore wing; pterostigma with apical margin infuscate 5
5. Frons densely setose; face largely and transversely rugulose; precoxal sulcus widely rugose; dorsal carina of first metasomal tergite only near dorsope ..... *Blacus (Ganychorus) setosifrons* Achterberg
— Frons sparsely setose; face smooth; precoxal sulcus and its surrounding striate; dorsal carina of first metasomal tergite almost reaching up to the apical margin ..... *Blacus (Ganychorus) hayati* Ahmad, sp.nov.

Blacus (Ganychorus) hayati Ahmad, sp. nov.
(Figs 1-4)

Female: Body length 2.5 mm; fore wing length 3 mm.

Head: Antennae 20 segmented, densely setose with short silvery-whitish setae; Fl 1.5x as long as F2, terminal segment 2x as long as penultimate segments; length of Fl, F2 and terminal segment 6, 4 and 3.5x their width; frons smooth and sparsely setose; OOL: POL: AOL: OD = 4:3:2.5:1; occipital margin somewhat crenulate; eyes in dorsal view about as long as temple; face smooth with a somewhat weak tubercle between antennal sockets; malar suture present; length of malar space about 1.2x basal width of mandible.

Mesosoma: Length of mesosoma 1.6x its height; sides of pronotum extensively reticulate rugose, but smooth dorsally; precoxal sulcus and its surrounding striate, few striae reaching up to prepectal carina and postpectal carina; notauli complete rather narrow and crenulate; mesoscutal lobe rather convex and setose; scutellum with few rugulae, lateral carinae not protruding dorsally; propodeal tubercles absent, surface



Figs: 1-4: *Blacus* (*Ganychorous*) *hyati* sp. nov.
1. Fore wing; 2. Head, frontal view; 3. Mid tarsal claw;
4. Propodeum, T1 and T2

of propodeum largely smooth, its median area absent; fore wing with first discal cell truncate anteriorly; 2-CU1 about 2.0x as long as 1-CU1; parastigma rather large; length of hind femur, tibia and basitarsus 6x, 9x and 8x their width respectively; fore and middle claw with blackish bristles and teeth; hind claw simple, only whitish (bristly) setose.

Metasoma: Length of first tergite 1.65x its apical width, longitudinally rugose, dorsal carinae almost reaching up to the apical margin; second tergite smooth; length of ovipositor sheaths approximately 0.16x of fore wing.

Colour: Dark reddish brown; palpi, mandible, ventral clypeus, tegulae, pterostigma (except infuscated margin of apical half), fore leg, mid leg, hind leg (except telotarsus), second and third tergite largely pale yellowish; face, vertex behind eyes, mesoscutum and apex of hypopygium yellowish brown; wings hyaline membrane, veins largely dark brown.

Male: Unknown

Holotype: ♀, India: Uttar Pradesh, Rampur; 13.iii.2003, Coll. Z. Ahmed (ZDAMU).

Paratypes: 1 ♀, same as holotype (ZDAMU)

Host: Unknown.

Distribution: India: Uttar Pradesh.

Etymology: The species has been named in honour of Dr. Mohammed Hayat for his contribution towards the knowledge of parasitic Hymenoptera.

Remarks: *Blacus* (*Ganychorus*) *hayati* Ahmad sp. nov. closely resembles *Blacus* (*Gancychorus*) *setosifrons* Achterberg, but differs in having frons sparsely setose (frons densely setose in *setosifrons*); face smooth (face largely transversely or obliquely rugulose in *setosifrons*); precoxal sulcus and its surrounding striate (precoxal sulcus widely rugose in *setosifrons*); dorsal carinae of first metasomal tergite almost reaching up to the apical margin (dorsal carinae of first metasomal tergite only near dorsope in *setosifrons*).

The type material is deposited in Zoological Museum, Department of Zoology, Aligarh Muslim University, Aligarh.

ACKNOWLEDGEMENTS

We thank Dr. M. Hayat and Dr. Shujauddin for reviewing the manuscript and offering useful suggestions. We are also thankful to Chairman, Department of Zoology for laboratory facilities.

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OBITUARY

HIMMATSINHJI

October 09, 1928 to February 22, 2008

With the passing away of Himmatsinhji on 22nd February, 2008, a remarkable tradition came to an end. Bawa Saheb, as he was affectionately called by the many recognized birdwatchers of Kachchh (the newly spelt name of Cutch), joined the Society as a Life Member on January 29, 1952 shortly after he completed his education. He already had a great knowledge of the birdlife of his area being the youngest of four sons of His Highness Maharajdhiraj Mirza Maharao Vijayrajji Sawai Bahadur, the Maharao of Cutch, who commissioned the Kachchh Ornithological Surveys by Dr. Sálim Ali during 1943-44 and financed the BIRDS OF CUTCH incorporating his and updating earlier publications of the birds of the region by several 19th century British ornithologists. These latter had all come in close contact with the Princely family and Himmatsinhji's Great Grandfather Maharao Pragmalji had commissioned a natural history museum in Bhuj. His Grandfather Maharao Khengar was among the founding members of the Bombay Natural History Society! It was he who informed the ornithological world of the existence of the immense nesting colony of Large Flamingos in the Great Rann of Kachchh and provided support for a visit to the site by the Society's McCann in 1939.

During the year preceding his passing away, Himmatsinhji was updating BIRDS OF CUTCH and he and I had a series of telephonic discussions on specific species, the last being a rather lengthy one on the Black-necked Stork. His phone came while I was actually watching a pair of the storks on the Jamnagar side of the Gulf of Kachchh! We agreed to meet in Kachchh during the first half of the next year (2008): to my eternal regret, it was not to be.

The era in which Himmatsinhji grew up with its English governesses, and British and Indian private tutors effectively ended to the swirling bagpipe tunes of regimental bands as the English marched through the India Gate of Bombay (now Mumbai) to embark on the waiting barges to take them to the troop ships lying in the harbour followed by Pandit Jawaharlal Nehru's midnight "Tryst with Destiny" speech to the Indian Parliament. He had just left the Rajkumar College, Rajkot in June of 1947, and gone up to the Bombay University to study agriculture at the Wadia College, Pune. He took to the new era with considerable verve entering the hurly burly of politics and defeating the then formidable Congress Party to represent Kachchh as the Member of Parliament from 1962 to 1967. I had the privilege of touring Kachchh with him at the wheel on a couple of occasions and I vividly remember the visit we made to the Chachhlo Dhand where I photographed a magnificent male Great Indian Bustard with the massif of the extinct volcano Dhinodhar in the background. He delighted in taking us to Vijay Villas Palace set amidst fine mango orchards on the Mandvi seacoast and I could visualize his childhood there getting familiar with the great variety of birds that visited the gardens. In the background were Casuarina plantations and magnificent sand dunes overlooking the Mandvi beach. He spoke of the Houbara Bustards that wintered there and the several species of Falcon that hunted for Larks and Buntings among the grass covered dunes. It was here that he recorded the Racquet-tailed Drongo and the Scarlet Minivet. The former he collected and sent to the BNHS, the latter observation accepted by the Society reflecting the total faith that Sálim Ali reposed in his expertise. Years later, when I suggested that he might have seen the migratory Long tailed Minivet from the Western Himalaya, his response was so typical of him: "You have totally floored me!" There was a great mutual respect between us throughout the long association which his passing away terminated. I had always felt he should have far, far more notes and articles on the birds of his area than the few notes that he did write, but when I did once remonstrate, he gently smiled and responded "This like a pot calling the kettle Black!"

The birdwatchers of Gujarat had arranged a grand meet at Hingol gadh on February 24, to remember all the past ornithologists like Maharajkumar Dharmakumarsinhji, Dr. Sálim Ali, and Shivrajkumar Khachar and to felicitate me on entering my 78th year. While not expecting him to attend in person, we had anticipated a message from him, instead, his passing away on February 22, converted the get together into a meeting of condolence for a much loved member of our fraternity.

Himmatsinhji married Princess Padmini Kumari of Wankaner, a family of naturalists in their own rights. She preceded him by a little over a year. Himmatsinhji is survived by a daughter and two grandsons and one granddaughter. The several knowledgeable birdwatchers of Kachchh feel orphaned and the Society has lost a loyal member who cherished memories of Dr. Sálim Ali and other staff of the Society who had worked in Kachchh during the "Mist Net" operations in the late 1950s and early 1960s.

LAVKUMAR KHACHAR

REVIEWS

1. ECOLOGICAL ENTOMOLOGY: INSECT LIFE IN ODD ENVIRONMENT by T.N. Ananthakrishnan and K.G. Sivaramakrishan. Scientific Publishers, Jodhpur, 2008. 142 pp. Size: 24.5 cm x 16.5 cm. Hardback. Price not given.

This technical book is written by two professors who are expert in this field, so the book is full of interesting information and erudite statements. But, unfortunately, it suffers from very serious editing problem. Scientific Publishers churns out scientific books regularly and should hire a good editor as most of the books published by them, which I have read or reviewed, have this problem. In this book, for example, there are many spelling mistakes, hyphen is missing (*microarthropods* instead of *micro-arthropods*), quotation marks begin but do not end (p. 8), words are wrongly placed ('*Tritaeniorhynchus* (Fig. 4) sp.,' instead of '*Tritaeniorhynchus* sp. (Fig. 4),' p. 15), a number of references are not listed under 'References', e.g. Hanski (2005) on p. 6, La Salle and Gauld, 1993. Some references are incomplete, e.g. Kumar and Prasad on p. 136 does not mention the year of publication and the complete title of the paper. In a scientific book, the term 'etc.' should be avoided. For instance, after mentioning the names of 2-3 species, if a person writes 'etc.', a layman would not know the names/numbers of additional species. Sometimes there are very complicated sentences, while in other places, disjointed statements are given. Due to bad editing, there is lack of clarity in many statements. For all these mistakes, I would blame the editor and the publisher of the book. I hope that Scientific Publishers avoid such mistakes in their future books.

The science in he book is good. The only problem is that too many ideas and facts are cramped in one small book. Perhaps the writers, both distinguished scientists, should write a more detailed book on this very important aspect of biodiversity, which is generally neglected. Interesting information is given which should be extensively quoted by conservationists to emphasize the importance of maintaining natural ecosystems, not only for glamorous large vertebrates, but also for maintaining our life-support systems. For example, on p. 13, the authors have mentioned how "the aquatic insect family and generic richness was higher in the streams with natural riparian vegetation than with the human modified ones ..." As biologists, we all know this but let the decision makers, who do not think even once before allowing a stream to be dammed or allowing a polluting factory to be built, should also know such facts.

I think such books are required to learn the importance of so-called lower organisms in the functioning of our natural world. The last chapter "Conservation for Healthier Environment" is rather brief (3 pages), but full of advice. I hope some of our decision makers will read this book, or at least the last chapter.

■ ASAD R. RAHMANI

2. AN INTRODUCTION TO ORNITHOLOGY AND BIOLOGY OF THE BLUE ROCK PIGEON by B.N. Bhattacharyya. New Central Book Agency (P) Ltd, Kolkata, 2008. 383 pp. Size: 24 cm x 18 cm. Hardback. Price not given.

This is a strange book, with a strange title. It is not clear whether the author wants to write a book on ornithology in general, or a book on the biology of the Blue Rock Pigeon. It is also not known whether this book is for experts or for students. If it is for experts, there is nothing new in this book that is not available in other more scholarly books. And, if it is for students, the zoological aspect is fine, but the natural history aspect has numerous mistakes. The diagrams of birds would not inspire any young student to take up ornithology as a profession.

The book is not well-researched, resulting in many false or wrong statements. For example, it is wrong to say that "Black Drongos (*Dicrurus* sp.) ... have almost equal preference for fruits, berries, figs, flower-nectar and insects." I have never seen a drongo feeding on berries and fruits. According to this book, gulls and terns feed on fishes, curstaceans (*sic*), insects, slugs and shoots of various crops. I still have to see terns feeding on shoots of 'crops'.

The book has outdated information. The preface was written by the author in October 2007 and the book was published in 2008, but the author still writes that the White-backed vulture (p. 251) "has fast declined in numbers since 1990s, possibly due to some infectious viral or bacterial diseases or toxicity and indiscriminate use of pesticides in carcasses." In the following paragraphs, he is more sure about the cause. "It is now been found that the infectious disease is possibly caused by a viral attack." By 2004 it was conclusively proved that diclofenac sodium, a pain-killer

given to cattle, is the sole cause of the dramatic decline of *Gyps* species of vultures in South Asia. It is rather strange that the author has not seen latest scientific papers on this issue.

As an introduction to the author, it is mentioned that he has published "number of research papers in several national and international journals of high repute. Four of his important papers were published in Germany in the internationally acclaimed Morphological Journal (Morph. Jb)". However, a quick glace at the Reference section shows that only four of his papers, all published in India, have been referred in this book (p. 357). There is one more paper, in Bengali (p. 367) with Bhattacharyya as a second author. It is rather strange that the author has not referred to his own four important papers (on morphology of birds, I presume) in his book on the subject of morphology which is dealt in great detail in seven chapters. The second part of the book, about the Blue Rock Pigeon, basically deals with its morphology and internal organs in about 90 pages.

I suggest that if the author plans to revise this book or write another book, he should consult the latest literature (easily available on the internet these days), and also hire a good artist. Our feathered friends, including the dowdy Blue Rock Pigeon, deserve a better treatment.

■ ASAD R. RAHMANI

3. PLANTS OF BASTAR, CHHATTISGARH: A FIELD GUIDE by Madhu Ramnath, Published by the Netherlands Committee for the International Union for Conservation of Nature (IUCN-NL), 2006. 568 pp., Size: 24.2 cm x 16.7 cm. Hardback Price not given.

PLANTS OF BASTAR CHHATTISGARH, A FIELD GUIDE by Madhu Ramnath has been in the making for nearly 15 years. This comprehensive work has been undertaken by a dedicated scientist and covers many species and genera not usually studied with the vegetative characteristics of plants in mind.

The book came into being as the author found the existing floras for the region quite unhelpful for a major part of the year as the usual plant keys depend mostly on flowers and fruit for plant identification. The lack of field guides for plant identification made the author attempt one for the limited area of central Bastar; however, many of the plants found in this region are also a part of the larger Indian landscape.

Bastar is the southern most district of Chhattisgarh which borders onto the Indian states of Orissa to the east, Andhra Pradesh to the south and Maharashtra to the west. Most of the Bastar district is a plateau with varied elevations between 284 and 1,200 m above msl. The rock structure of the plateau has been denuded over millions of years and is of crystalline formation. The average rainfall is 1,538 mm most of which occurs during the south-west monsoon months between June and September. There are, on average about 75 wet days in the year with the rest of the seasons being relatively dry and cool, although no frost occurs. The forests of Bastar are dominated for the most part by Sal *Shorea robusta* although there are some stands of Teak *Tectona grandis* in certain areas, but Sal gives the area its specific character. On some hill slopes trees of the genera *Terminalia*, *Haldinia* and *Pterocarpus* are predominant. In the rocky areas are found trees of *Sterculia, Gardenia, Phoenix, Xylia* and *Euphorbia* with some types of bamboo. And along streams and watercourses the predominant trees are the mango, and *Diospyros*.

The people of Bastar with whom the author lived and worked for several years have been invaluable with their knowledge of plants as their lives depend on the products of the forests. It is with their help that the author travelled extensively in the forests of Bastar, often camping overnight along streams, and learnt to notice characteristics of plants not mentioned in most traditional keys. The local uses and names of many of the plant species listed in the book are also clearly indicated.

An important purpose of this book is to reveal the traditional use of plants as practised by the Durwa and Koitoor peoples of Bastar and adjacent parts of Orissa. Many of the plants used such as *Mangifera*, *Holarrhena*, *Semecarpus*, *Bauhinia* and *Buchanania* are never planted; though used on an almost daily basis and form the predominant vegetative composition of the forest. As the author points out 'In these times of forest loss and skewed development programmes it might be rewarding to extend such methods and practices of plant use that have stood the test of time to a long-term vision of forest conservation.'

The classification followed in the book is the sequence of families and order given by G.L. Stebbins from his FLOWERING PLANTS – EVOLUTION ABOVE THE SPECIES LEVEL (1974) and Heywood's FLOWERING PLANTS OF THE WORLD.

While using this book I have found the vegetative key most useful both for the line drawings, done by Elly Oenema, and the elaborate vegetative descriptions of plants. The excellent index at the back of the book gives both vernacular and scientific names. I have also appreciated the section of tree barks clearly photographed for quick identification and the clarity of language and illustrations of the various genera and species described. The print is large and easy to read and

the descriptive word usage simple. Another feature is that flowering times are noted and under each species is a list of species numbers available in both India and the world if this is known. A useful addition is the translation of Latin words describing the various species and genera in the botanical nomenclature. This clarifies, on many occasions, the very substance, location, or meaning of the words which scientists used in naming the plant or tree.

The additional keys for fruit and flower characteristics is extremely helpful in cross-referencing, especially since many plants remain without flowers or fruit for a very large part of the year. This additional set of keys should be of great value to the field botanist. I hope that the plant families that have not been included in this volume will be added to in the future; I have found this book extremely useful to enhance my knowledge even though many of the genera and species in Tamil Nadu, where I live, are different. The book is easy to use for the less experienced plant lover because of its clarity.

The book has been published by the Netherlands Committee of the IUCN who, along with the Stichting van Tienhoven, at Leiden in the Netherlands, provided the financial support. The Kew Gardens in London, the Rijksherbarium in Leiden, and the Rapinat Herbarium in Tiruchirapalli have helped the author with technical support and access to their collections.

I highly recommend this volume to plant lovers and curious field botanists both from India and abroad.

■ PIPPA MUKHERJEE

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MISCELLANEOUS NOTES

1. PRELIMINARY INVESTIGATIONS CONFIRMING THE OCCURRENCE OF INDUS RIVER DOLPHIN *PLATANISTA GANGETICA MINOR* IN RIVER BEAS, PUNJAB, INDIA[1]

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The Indus River Dolphin *Platanista gangetica minor*, or 'Bhulan' as it is locally called, was considered endemic to Pakistan as it was reported only in the Indus river system. More than a hundred years ago, the Bhulan occurred in the Indus and its four major tributaries, the Chenab, Ravi, Sutlej and Jhelum, where it was distributed from the foothills of the Karakoram range to the Indus Delta (Anderson 1878; Roberts 1998). It is currently found in only a small portion of its former range, a stretch approximately 600 km long. Small scattered populations consisting of 2-3 individuals are found, isolated between irrigation barrages. These subpopulations are not ecologically and genetically viable (Reeves *et al.* 1991; Reeves and Chaudhry 1998). The Indus Dolphin has been classified as 'Endangered' (IUCN 2006) (Criteria: A2abcde; B1ab(i,ii,iii,iv); C1) (Population Trend: Decreasing).

On the request of the State Forest Department of Punjab, the World Wide Fund for Nature - India conducted field surveys from December 20-22, 2007 to confirm the occurrence of the dolphins in the Harike Wetland Sanctuary. Surveys were conducted using a motor boat and the observations were recorded using binoculars and reading of locations was made using a GPS. Photographs and high definition videographs were also taken. A stretch of 60 km was intensively searched from Harike Lake Notch (31° 9.03' N; 74° 57.09' E) to Karmowala Village (31° 10.57' N; 075° 2.46' E), and back to the Harike Lake Notch, covering different channels. Informal interviews with locals were also conducted to ascertain the presence of the dolphins.

Failing to record any dolphin on the first day, we modified the survey methodology slightly on the second day by deputing four observers at different vantage points within the identified habitat of dolphins and instructed them to contact the team members in the motorboat as soon as they sighted dolphins. For the first half of day two, between 0930 and 1330 hrs the field survey was conducted in the downstream of the confluence of the rivers Beas and Sutlej, but no dolphin was sighted. It was then decided by the first author (SKB) to visit the nearby upstream villages and conduct interviews with locals. We covered about 40-50 km along the banks of the River Beas, interviewing local villagers and at about 1700 hrs we reached the Karmowala village (Tarn Taran district), about 25 km upstream of the Sutlej-Beas confluence. We came across a local ferry service man who immediately took the team to the place where he had earlier seen the dolphins. When the team reached the site at 1730 hrs after walking along the banks for 2-3 km, a group of dolphins, which consisted of two adults and three calves, was sighted. On the third day of field visit, few more habitats suitable for dolphins were identified in the Beas river from the Harike lake, and 25 km upstream. Dolphins were sighted in two of these habitats (31° 13.37' N; 75° 3.79' E) and (31° 13.33' N; 75° 4.02' E).

Interviews with the fishermen and local community revealed the sightings of a small population of dolphins in the recent past, namely the last three months at the same locations where we sighted the dolphins. Elderly people from the village community and the fishermen informed us of the presence of dolphins in the Beas river stretch over the last few decades. The villagers also informed us about the presence of Gharials in 1980s and confirmed the presence of otters and turtles.

Although the dolphins we sighted in River Beas looked like the Indus River Dolphin we need further confirmation. It is assumed that this is a sub-population of the Indus River Dolphin, separated from the main population after the construction of barrages along the Indo-Pakistan border in the 1950s.

Gill Braulik informed "Earlier this year we (Pakistan Wetlands Programme/WWF-Pakistan) conducted interview surveys on all of the Indus tributaries in Punjab to establish the date of extirpation of dolphins in these rivers. There is evidence that the Indus dolphins existed upstream of Suleimanki Barrage on the Sutlej until 1989. Suleimanki is 140 km downstream of Harike. Given that the Sutlej in

Pakistan was recently inhabited by dolphins, it seems likely to me that the dolphins in India are a remnant, previously undiscovered subpopulation, rather than that they moved here recently from elsewhere. The closest Indus dolphins are approximately 600 km away in the Indus River". Looking at the present situation on the Sutlej and Beas rivers in India, it is quite impossible for the movement of the species as the barrage gate on the Indo-Pak border area is totally blocked with limited seepage water flowing into Pakistan. As per the information gathered from the locals, Beas is a free flowing river after the Pong dam and has a good depth and flow with less visible pollution. River Beas and its tributaries may have other dolphin populations that need to be identified through detailed surveys.

The River Sutlej was found to be visibly polluted (black coloured water) with a limited flow (shallow) and heavy growth of the Water Hyacinth *Eichornia crassipes*, and is therefore an unsuitable habitat for dolphins. The confluence with River Beas presents a contrasting picture. River Beas is comparatively less polluted (murky water) with a high flow and presence of deep pools/counter eddy currents/shallow riffle areas/islands in lower stretches (from the confluence upstream 25 km) and forms a suitable habitat for dolphins. However, upstream of the Harike Lake, the habitat is subjected to disturbances such as agricultural activities, ferry services and fishing.

ACKNOWLEDGEMENTS

We acknowledge the encouragement and support of Mr. Ravi Singh (Secretary General & CEO) WWF and Dr. Parikshit Gautam (Director, Freshwater & Wetlands Programme) to take up this study. The forest personnel of Punjab State Forest Department, in particular to Malkit Singh and Sukhpal Singh are thanked for providing infrastructural support. Dr. Anish Dua and Mr. Chander Prakash (Guru Nanak Dev University, Punjab), and the local villagers are also thanked for their support in field work. We are grateful to Dr. Asad R. Rahmani (Director-BNHS) for revising the earlier draft of the manuscript.

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2. LOCATIONS OF SIND SPARROW SIGHTINGS ALONG THE RAJASTHAN CANAL AND THE RIVER SUTLEJ[1]

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In the Indian subcontinent, the Sind Sparrow *Passer pyrrhonotus* is virtually restricted to the floodplains of the River Indus delta and its major tributaries, the Sutlej and Ravi rivers, north to about 34° 6' N (Clement *et al.* 1999). Its Indian range is described as the Indian Punjab on the Beas river near Gurdaspur and along the Sutlej from Harike, east to the bridge on the main road between Ludhiana and Jullunder (Jalandhar), but not further upstream at Rupar (Summers-Smith 1988). It has recently colonised the Yamuna flood plain in eastern Haryana and north Delhi, but remains extremely scarce and local everywhere (Harvey and Sharma 2002).

This note concerns its recent occurrence in Hanumangarh district of Rajasthan. We have been regularly visiting this area since the last fifteen years or so, but have never come across this species before.

On April 23, 2001 one male and two female Sind Sparrows were found on a Kikar *Acacia nilotica*, on the bund of the Rajasthan Canal (Indira Gandhi Nahar) near Kulchandar and Saharni villages (*c.* 22 km from Sangaria) in Hanumangarh district, Rajasthan. On both sides of the canal there is a variety of *Acacia* scrub, tamarisk and grass jungle broken by large Kikar and Tali *Dalbergia sissoo*. These native trees are also present along the bunds of the canal to stabilize the soil.

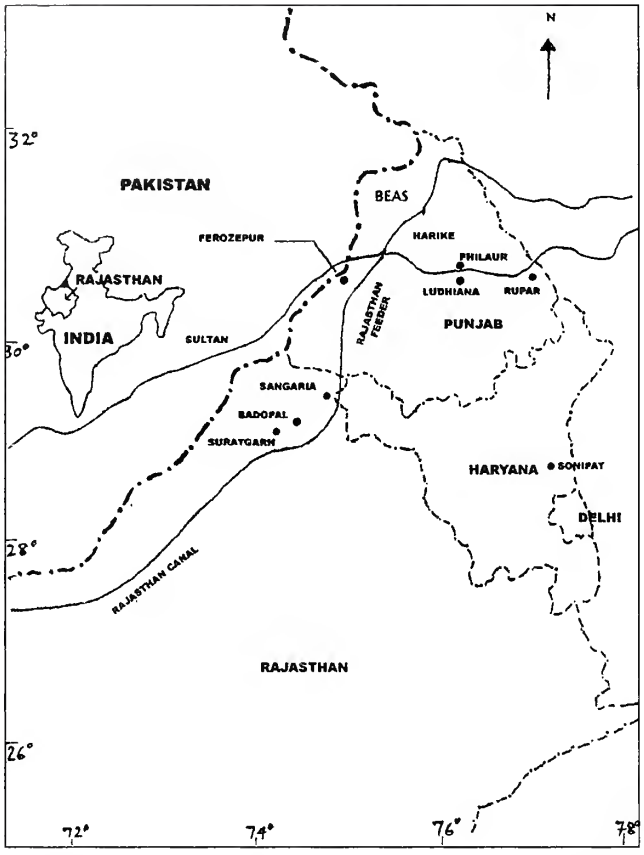

Fig. 1: Locations of Sind Sparrow sightings along the Rajasthan Canal and the river Sutlej

The species was sighted again in Hanumangarh district at Badopal lake near Suratgarh on March 01, 2002. Eight males and five females were counted in two separate groups on *Acacia tortilis* trees along the road. Two to three birds were observed picking food off the seed pods of the tree.

Apparently, the Sind Sparrow has had a restricted range since it was discovered, with only circumstantial evidence of even short distance migrations. It is a bird of tamarisk and *Acacia* scrub with tall grass or reeds along rivers, pools or marshes, invariably in close association with water (Clement *et al.* 1999). Although basically non-commensal, it has benefited from human activity. The extensive irrigation schemes undertaken after independence in 1947 have transformed the arid plains of the Punjab and Haryana. The lengthy canals, reservoirs and water bodies due to seepage from the canals have facilitated the species to colonise new areas.

The earliest records of the Sind Sparrow in the Indian Punjab are from the R. Sutlej side of Ludhiana, Phillaur and Ferozepur (Whistler 1911, 1913). A hitherto largely sedentary and localized species was first found in Haryana in 2001. The species successfully bred and was recorded from twelve sites in eastern Haryana and north Delhi during January-August, 2001 (Harvey and Sharma 2002).

Apart from the proximity of water, the major constant in the ecological requirement of Sind Sparrows appears to be the *Acacia nilotica* (Harvey and Sharma 2002). Circumstantially, the evidence is that the species has moved into northern Rajasthan recently along the Rajasthan Feeder Canal (Fig. 1). The canal starting from Harike, Punjab evidently provided the known ecological requirements for the species to expand its range. What other factors have helped the species to colonise new areas is not known yet, but it is clearly on the move.

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3. SIGHTING OF INDIAN SKIMMER *RYNCHOPS ALBICOLLIS* (SWAINSON) IN THE PURBASTHALI-GANGES ISLETS, BURDWAN DISTRICT, WEST BENGAL[1]

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The globally threatened Indian Skimmer *Rynchops albicollis* has a large range with an estimated global 'Extent of Occurrence' of 2,52,000 sq. km. It has a global population estimated to be 6,000-10,000 individuals (Wetlands

International 2002). This species is listed as Vulnerable (Birdlife International 2007) because its population is undergoing a rapid decline as a result of widespread degradation and disturbance of lowland rivers and lakes. The Indian Skimmer is confined to Pakistan, India, Bangladesh and Myanmar. A large proportion of the population of this species winters in Bangladesh, principally in the Padma-Meghna delta, and Myanmar. It is a rare visitor to Nepal. It was formerly widely distributed across the Indian subcontinent, along the major rivers of Myanmar, and along the Mekong in Indo-China. In India its distribution range is mainly confined to the River Ganga. It has declined in India and Pakistan (Birdlife International 2007). As per the published account, from West Bengal it has been recorded from the Buxa Tiger Reserve (Allen *et al.* 1996) in the Jalpaiguri district, from the Farakka Barrage in the Malda district (Jha 2006; Sharma 2001) and from the Chattaranjan Bara Dam in the Burdwan district on January 30, 2003 where nine individuals were recorded (Bombay Natural History Society 2007).

From January 26-28, 2007, I went to Purbasthali-Ganga Islets for a survey on waterbirds. The Purbasthali-Ganga Islets situated in the Burdwan district is adjacent to Nadia district in West Bengal. The vast riverine tract of Purbasthali is located close to Kasthashali in Chupi Char along River Ganga. This wetland complex is actually a cluster of riverine isles, ox-bow lakes and river channels. A large number of migratory waterbirds, especially waterfowl are found here.

As the Indian Skimmer is a Vulnerable species, here I give recent sight records. On January 26, 2007 at 1220 hrs I noticed four Indian Skimmers resting along the riverbank at the Nidoya Char. Further upstream of the river at 1345 hrs two individuals were sighted hovering above the waterline at the Rajar Char. On January 27, 2007 at 1150 hrs two individuals of this species were sighted at the same spot at the Nidoya Char. On the same day at 1410 hrs at the Rajar Char a group of four individuals was sighted on the riverbank side. On January 28, 2007 at 1215 hrs a group of six individuals was sighted at Nidoya Char. It appears that the Nidoya Char is a suitable foraging ground for this species, as this species was sighted only here everyday.

The Purbasthali-Ganga Islets is an unexplored waterbird habitat of West Bengal. It is estimated that the Purbasthali-Ganga Islets support at least 72 species of waterbirds and are ranked as a top priority list to be designated as a Ramsar Site (Vijayan *et al.* 2004). Recently, I recorded 101 species of waterbirds from the Purbasthali-Ganga Islets (Sharma 2007). It was found that this wetland area is suitable for Indian Skimmers also, where it may occur regularly.

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4. FIRST RECORD OF CASPIAN GULLS *LARUS CACHINNANS* IN THE INDIAN SUNDERBANS DELTA[1]

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On January 24, 2005, we approached Halliday Island Sanctuary, located at the extreme end of the Indian Sunderbans delta near the Bay of Bengal coastline, which is a part of the Sunderbans Biosphere Reserve, to look for waders. The survey was a part of an international ornithological expedition looking for the globally threatened Spoon-billed Sandpiper *Eurynorhynchus pygmeus* (Zöckler *et al.* 2005). The Island is situated south-east of Kolkata in South 24 Parganas district,

West Bengal, India, a World Heritage Site (Project Tiger 2001).

While approaching the island, we noticed a group of gulls hovering above the waterline flying along our launch, the birds appeared to be following us. We arrived at the Halliday Island Sanctuary at *c.* 1245 hrs and began identifying and counting the waders present there. After completing the wader count we turned our attention to the gulls, which were still hovering above the waterline near the shoreline. After close observation from a distance of *c.* 200 m, through telescopes, we noticed there were fifteen gulls in the group of which nine were Caspian Gulls *Larus cachinnans*, five were Pallas's Gulls *Larus ichthyaetus* and one Sooty Gull *Larus hemprichii*. All the gulls were in their adult winter plumage (Grimmett *et al.* 1998; Kazmierczak and van Perlo 2000; Couzens 2005; Ripley *et al.* 2005).

The plumage of the Caspian Gulls *Larus cachinnans* was recorded as: Overall appearance dark uniform brown and considerably smaller than the neighbouring Pallas's Gulls; head, nape and throat slightly brownish with a short whitish eyebrow. Underparts whitish. Mantle and wings brown. Wings dark brown with darker blackish primaries (did not show underparts). Through the telescope the bill looked heavy, quite slim with little gonydeal angle; moderate to steep curve to culmen. Head small and rounded, on a rather slim, graceful neck; impart a more delicate look (Grimmett *et al.* 1998; Kazmierczak and van Perlo 2000; Ripley *et al.* 2005). However, other individuals of the same species on the island had yellow legs, gray back, slightly darker and more extensively black wing tips with a few white spots. A red spot on the bill and a red ring around the eye; orb ring red to orange-red in colour. Tail and rump white. Head white with variable fine streaks from eye to rear crown. Iris noticed dull gray-yellow to bright lemon. Bill colour bright to orange-yellow. Gonydeal spot large and red.

The breeding range of the Caspian Gull is concentrated on the Mediterranean Sea. In North Africa it is common, and in Morocco, Algeria and Tunisia the population is known to be increasing. Recently, breeding of this species in Libya and Egypt has been recorded. In the Middle East, a few breed in Israel and Syria with large numbers in Cyprus and Turkey. In Europe, there are colonies all along the Mediterranean coast and it also breeds on the west side of the Black Sea. The Caspian Gull is also common in the Canary Islands, Madeira Islands and the Azores. Many birds remain in the same area all year round, but others migrate to spend the winter in warmer areas of Western Europe or head southwards, as far as Senegal, the Gambia and the Red Sea. It is reported as a vagrant to north-eastern North America and Nigeria (BirdLife International 2007).

Caspian Gulls, a widespread winter visitor to the Indian subcontinent, have been recorded from various parts of India; but unfortunately the status of this species from India is uncertain and uncommon (Grimmett *et al.* 1998). Caspian Gull was not recorded from West Bengal as indicated in the range maps of this species (Grimmett *et al.* 1998; Kazmierczak and van Perlo 2000). In the neighbouring country of Bangladesh it is a scarce winter visitor, mainly in the Bangladesh Sunderbans (Jhonson *et al.* 1992; Grimmett *et al.* 1998). We are sure that the species occurs in the Indian Sunderbans delta in considerable numbers and may have been overlooked. The recent sighting of Caspian Gulls from the Halliday Island Sanctuary is probably the first record of this species from the Indian Sunderbans delta and West Bengal, India.

ACKNOWLEDGEMENTS

We gratefully acknowledge Mr. Mrinal Chatterjee and Mr. Debdas Bhakta of the Institute of Climbers & Nature Lovers, Anpur, Satjelia Island, Sunderbans for their cooperation and assistance and all the individuals who took us to the remote areas of the Indian Sunderbans delta for bird surveys and protected us while we counted waders in known tiger areas. Finally, we thank the German Manfred Hermsen Foundation, Bremen for generously funding the survey.

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5. A RECENT OBSERVATION OF WHITE-HEADED DUCK *OXYURA LEUCOCEPHALA* AT GAJALDOBA BARRAGE, WEST BENGAL, INDIA[1]

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On February 03, 2006, while scanning a few thousand waterbirds at the Gajaldoba Barrage, Jalpaiguri district, West Bengal, India, we observed a female White-headed Duck *Oxyura leucocephala*, loosely associated with a large mixed group of anatids (mostly the Common Teal *Anas crecca* and the Gadwall *Anas strepera*, with smaller number of Northern Shoveller *Anas clypeata*, Northern Pintail *Anas acuta*, Eurasian Wigeon *Anas penelope*, Mallard *Anas platyrhynchos*, Falcated Duck *Anas falcata*, Red-crested Pochard *Netta rufina*, Tufted Pochard *Aythya fuligula*, Common Pochard *Aythya ferina* and Ferruginous Pochard *Aythya nyroca*). The bird was easily identified by its typical shape with a long tail held in upright position, a large head and swollen-based bill, its uniformly rufous-brown body and the black and white head pattern. Sex identification was based on the extensive black cap reaching below the eye, off-white face with broad dark cheek-stripe and blackish bill.

Most of the time the White-headed Duck was not closely associated with other ducks but was observed swimming around busily in open water at the edge of the flock near to the dam. Although the bird was very active, it did not seem to be in a sound health condition as it was continuously opening its bill, giving the impression that it had respiratory problems.

Gajaldoba Barrage is an artifical wetland created by retaining the water of Teesta river. It is an important wintering and stopover site for migratory ducks and shorebirds, and has a considerable potential of attracting rare birds. Other significant species which were observed during two visits on January 15 and February 03, included the Black-necked Grebe *Podiceps nigricollis*, the Common Shelduck *Tadorna tadorna*, the Common Goldeneye *Bucephala clangula* and the White-tailed Sea-Eagle *Haliaeetus albicilla*.

Discussion

The White-headed Duck is distributed in Central Asia and some parts of Europe. It is globally threatened and classified as Endangered by BirdLife International and IUCN (BirdLife International 2006). Its world population has decreased from probably over 100,000 individuals in the early 20th century to an estimated 19,000 in 1991, and has probably declined to less than 10,000 since (BirdLife International 2006). Main threats include the habitat loss in Central Asia, where approximately 50% of breeding habitat has been drained during the 20th century, pollution and recent droughts in Kazakhstan and Uzbekistan (BirdLife International 2006). In the Indian subcontinent, the wintering population of the White-headed Duck is mainly restricted to Pakistan, where the number has dropped from 1,039 birds in 1968 to only 5-33 between 2002 and 2004 (Li and Mundkur 2003; Zulfiqar and Akhtar 2005; BirdLife International 2006). In India, the species is now very rarely recorded with only two observations since 1980: single birds at Harike Lake, Punjab, in 1984, and at Amakhera wetland, Uttar Pradesh, in 1997 (Li and Mundkur 2003). The present record of White-headed Duck from Gajaldoba Barrage is far east from its usual occurence in South Asia. However, there are old specimens from Calcutta market, West Bengal, which have presumably been taken nearby (Rasmussen and Anderton 2005). In China, where the species is very rare, single birds have been observed as far east as Hunan and the Inner Mongolia Autonomous Region (Li and Mundkur 2003). These records, as well as the recent observation from Gajaldoba Barrage, most likely refer to vagrants.

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6. A LARGE CONGREGATION OF COTTON TEAL *NETTAPUS COROMANDELIANUS* OBSERVED AT CHILIKA LAKE, ORISSA, INDIA[1]

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On January 11, 2003, one of us (PS) participated as a group leader of one of the 14 groups formed among the participants of the Mid-winter Waterfowl Count organised by the Chilika Wildlife Division at Chilika Lake, Orissa. The area allotted to the group was Tinimuhani, the confluence point of the three tributaries of Mahanadi, namely the Daya, Bhargavi and Nuna, in the northern sector of the Lake. The bulk of the freshwater inflow into the Lake is through these three tributaries. The census team left Balipatpur Jetty (19° 0.92' N; 85° 0.49' E) at 0900 hrs. PS was counting the bird numbers species-wise and D.K. Parmanik, an Assistant Conservator of Forests, was recording the numbers in the field notebook. Around 1200 hrs the group approached a major bird congregation area at Tinimuhani. The area was filled with waterfowl; predominantly – Eurasian Coot *Fulica atra*, Cotton Teal *Nettapus coromandelianus*, Red-crested Pochard *Netta rufina*, Pheasant-tailed Jacana *Hydrophasianus chirurgus* and Tufted Duck *Aythya fuligula*. Over one thousand Whiskered Tern *Chlidonias hybrida* over-flying and often resting on the fish net poles were also observed. We counted about 5,400 Cotton Teals.

When SB visited the same area for a fortnightly bird monitoring along with PS during the first week of March, the former saw about 1,600 Cotton Teals. When PS mentioned the earlier sighting of 5,400 birds to SB, during the Mid-winter Waterfowl Count, he was surprised. We realised that this record was the largest known congregation of this species. The HANDBOOK (Ali and Ripley 1983) records 500 birds as the congregation of Cotton Teal in an area. Sridharan (1989) recorded 562 individuals of the species from the Keoladeo National Park. It is worth to mention that Benthall and Craven (1950) stated that the Cotton Teal was scarce in the Chilika Lake. Moreover, this record of 5,400 Cotton Teal is also more than 5.4% of its biogeographical population as per the estimates given by the Wetlands International Waterbird Estimates of 2006 (Wetlands International 2006). On another occasion a total of 5,200 birds were recorded by SB during the first week of January 2006 from the same area. These records suggest that a large occurrence of Cotton Teal at Chilika is regular, not occasional. This also highlights the importance of the Chilika lake for the resident waterfowl species, besides its global importance of holding the largest migratory waterbird congregation in India.

ACKNOWLEDGEMENTS

We are grateful to Mr. J.C. Daniel, Honorary Secretary, and former Director BNHS for reading the manuscript We would like to express our sincere thanks to the Chilika Development Authority, Govt. of Orissa, for funding this project, and Chief Wildlife Warden of Orissa for granting necessary permission for the study. We greatly appreciate the hard work rendered by our field assistants Mr. P. Guruswamy and Mr. Niranjan Dalei.

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7. RECORD OF LARGE CONGREGATION OF LARGE WHISTLING-DUCK *DENDROCYGNA BICOLOR* IN THE PURBASTHALI-GANGES ISLETS, BURDWAN DISTRICT, WEST BENGAL[1]

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Between January 26 and 28, 2007 I went to the Purbasthali-Ganga Islets for surveying waterbirds. During the survey I recorded a large number of Large Whistling-ducks *Dendrocygna bicolor* at various places in this freshwater river system. The Purbasthali-Ganga Islets is situated in the Burdwan district in West Bengal. The vast riverine of Purbasthali is located close to the Kasthashali in the Chupi Char along the River Ganga. This wetland complex is actually a cluster of riverine isles, ox-bow lakes and river channels. A large number of migratory waterbirds, especially waterfowl winter here.

On January 26, 2007 at 1015 hrs I first noticed a group of Large Whistling Ducks resting at the Kashthasali Char; I counted 895 individuals. Down the river at Idrakpur Char, another group of 780 individuals was recorded. Further down the river large groups of this species were found at Rajar Char (1,020), Kamal Nagar Char (982) and Rukunpur Char (743). The total numbar recorded on January 26, 2007 was 4,420 individuals. On January 27 and 28, the total number of Large Whistling Ducks was found to be 4,190 and 4,367 individuals respectively.

The total breeding population of the Large Whistling Duck in South Asia is 20,000 (Wetlands International 2002). The present record of Large Whistling Ducks from the Purbasthali-Ganga Islets indicates that this wetland complex supports more than 20% of the existing population of Large Whistling-duck in South Asia. The Purbasthali-Ganga Islets, therefore meet the criteria to be protected and designated as an Important Bird Area under the A4i category (Islam and Rahmani 2004). The Purbasthali-Ganga Islets has been evaluated as a top priority for designation as a Ramsar site (Vijayan *et al.* 2004).

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8. TWO OBSERVATIONS OF MALAYAN NIGHT-HERON *GORSACHIUS MELANOLOPHUS* FROM WEST BENGAL, INDIA[1]

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On May 03, 2005 around noon, Peter Logtmeijer (PL) and Wouter Puyk observed an adult Malayan Night-Heron *Gorsachius melanolophus* at Mahananda Wildlife Sanctuary (WLS) near Siliguri in Jalpaiguri district, West Bengal, India. The bird was flushed from near a fallen tree in a dry and stony riverbed in the eastern part of the Sanctuary, along the Siliguri -Kalimpong road. The Night-Heron was seen well at a distance of 20-30 m before it disappeared into the forest. The first impression of the bird was that of a small Eurasian Bittern *Botaurus stellaris*, with a large head and stout bill, broad rounded wings and legs projecting behind the tail. It looked smaller in size than a Black-crowned Night-Heron *Nycticorax nycticorax*. The upperparts and sides of the neck were rufous-brown except for the black crown/crest, which

reached down to the neck. The wing coverts were also rufous-brown, with the primaries and secondaries appearing black. The primary coverts and/or the base of the primaries showed distinct white barring.

On February 03, 2006 before dawn, AT and MR watched birds from a bridge crossing a small stream inside Baikuntapur Forest, which adjoins the south-eastern part of Mahananda WLS. The stream had dried up except for two large puddles near the bridge. While watching a number of passerines, including the White-tailed blue Robin *Myiomela leucura*, the Pale-chinned Flycatcher *Cyornis poliogenys* and the Snowy-browed Flycatcher *Ficedula hyperythra*, dropping in for a bath, AT spotted a small stocky night-heron slowly moving towards us underneath a line of bushes at the edge of the stream. The initial distance was about 30 m. The head, neck and breast were rich rufous, the crown and the longish crest were black. Upperparts and wings showed dark vermiculations on rufous background. Foreneck and breast showed black streaking, and the belly was whitish with dark markings. The short, stout bill was yellowish; eyes were yellow with black pupils. The facial skin and legs showed bluish-green coloration. The bird was easily identified as an adult Malayan Night-Heron. We watched it through binoculars and a telescope down to a distance of 15 m, as it slowly moved along the pond in search of food for about 20 minutes, after which it got too dark. It showed a very striking behaviour, constantly moving the neck slowly sidewards, describing a sinuous line.

Both observations were in subtropical lowland evergreen Sal forests, which are veined by a mosaic of rivers and small streams. The soil is covered with low shrubbery, while mid-height vegetation is scarce and mainly found along streams.

The Malayan Night-Heron is locally distributed in India, China, Southeast Asia and the Philippines, and is migratory, at least in the northern parts of its range. It is generally uncommon and secretive, living in swampy areas in dense lowland broad-leafed evergreen and mixed deciduous forests, and feeding mainly at night. In the Indian subcontinent, where it is local and scarce, it is said to be resident or partly resident in the Western Ghats and the central and southern Nicobar Islands, and a summer visitor in the area of Assam Valley to Manipur. In Sri Lanka, it is a regular winter visitor (Rasmussen and Anderton 2005). However, it has not previously been reported from West Bengal, and records from the north-eastern states of India are scarce. In Assam, it occurs among other places, in Kaziranga National Park, where it is said to be an uncommon migrant (Barua and Sharma 1999), Nameri National Park (rare migrant; Barua and Sharma 2005) and Dibru-Saikhowa National Park (rare; Choudhury 1997; Choudhury 1998). Malayan Night-Heron has also been reported from Nagaland, Manipur, Mizoram and Meghalaya (Choudhury 2001; Birand and Pawar 2004).

Our two observations from West Bengal are from locations about 10 km apart and are connected by a continuous protected forest. The Mahananda WLS and adjoining Baikuntapur Forest provide good habitat for the species, where it may occur regularly and perhaps even breeds, but hitherto it has been overlooked in the area due to its secretive habits. Intriguingly, the species is considered a summer visitor in India outside the Western Ghats and the Nicobar Islands. The north-east Indian population of Malayan Night-Heron is said to migrate south through the Haflong district (Ali 1962) and Burma (=Myanmar) between August and October, probably wintering in the Malay Peninsula (Glenister 1951) and Greater Sundas. Passage through the Malay Peninsula has been noted in October-December and April, and wintering birds have been recorded in Sumatra from November to May (del Hoyo *et al.* 1992). Our observation from early February is clearly out of season and may in fact be the first winter record of this species from the north-eastern part of India. We strongly recommend further search for the secretive and easily overlooked Malayan Night-Heron in the Mahananda WLS and neighbouring forests to resolve questions about its local status.

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9. NEW DISTRIBUTION RECORD FOR *CALOTES NEMORICOLA* JERDON, 1853 FROM THE KUDREMUKH HILLS, KARNATAKA, INDIA[1]

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Kudremukh National Park (KNP) is one of the less explored mountain ranges of central Western Ghats (Vasudevan *et al.* 2006). We conducted herpetological surveys for the Karnataka Forest Department from October 2005 to February 2006 in the KNP. On November 27, 2005, at 1600 hrs we came across a single specimen of *Calotes* sp. moving on the ground in an Areca nut plantation in the Pela village of the Belthangady range of KNP. This plantation is about 100 m from an evergreen forest at 400 m above msl. The specimen was fixed in 70% Ethanol and deposited in the Collections of the Bombay Natural History Society, Mumbai (BNHS Regn No. 1778).

The specimen was identified as *C. nemoricola* Jerdon (Smith 1935). The morphological and meristic data is given in Table 1. The coloration of this specimen was similar to Smith's description except for the presence of blue colour on the head and maroon colour on the nape. The sex of the specimen was not determined.

C. nemoricola is known from Munnar, Nelliampathy, Ponmudi hills and Wayanad in Kerala; Annamalai, Ashambhu, Mudumalai and Nilgiri hills in Tamil Nadu (Gunther 1864; Smith 1935; Whitaker and Das 1990; Tikader and Sharma 1992; Karthikeyan *et al.* 1993, Bhupathy and Kannan 1997; Thomas *et al.* 1997; Ishwar 2001; Ishwar *et al.* 2001). Thus, this new locality information extends the distribution of the species by *c.* 300 km north. It suggests that the species ranges widely throughout the central and southern Western Ghats.

Table 1: Measurements (in mm) of *C. nemoricola*

Character	Measurement (mm)
Snout to vent length	140.4
Tail length	324
Tail diameter at the base of the tail	11.9
Head length	38.3
Head width	22.7
Length of the IV toe from the junction of IV and V toe	29.9
Length of the longest nuchal scale	10.6
Diameter of the tympanum	3.9
Diameter of the eye	5.2
Supralabials (right/left)	11/11
Infralabials (right/left)	11/11
Around the body scale rows	38
Mid-dorsal crest scales	47
Right 4th toe subdigital lamellae	23

ACKNOWLEDGEMENTS

We thank the Karnataka Forest Department and their staff for funding, permission and support. We thank Dr. Karthikeyan Vasudevan and Shri. M.S. Chaitra for their guidance, support and encouragement. We are grateful to Mr. Dilip Venugopal and Mr. N.M. Ishwar for providing old site records of *C. nemoricola*. We thank Mr. Varad Giri for the information provided. We thank Mr. Shashank Dalvi and Ms. Swapna N. for their support during the survey and Mr. S.P. Vijayakumar for his critical comments on the manuscript. We express our sincere thanks to the anonymous referee for the valuable comments.

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10. RECORD OF BURMESE PYTHON *PYTHON MOLURUS BIVITTATUS* AND ITS CONSERVATION STATUS IN CORBETT TIGER RESERVE, UTTARAKHAND, INDIA[1]

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Two species of python (Family: Boidae) – *Python molurus* (Linnaeus) and *P. reticulatus* (Schneider), and two subspecies of *Python molurus* – *P.m. molurus* and *P.m. bivittatus* – are reported from India. These subspecies differ based on the following morphological characters: in *P.m. molurus* 6th or 7th labial contact the eye, lance-shaped mark on the top of the head is indistinct in adults and the tongue is pink, while in *P.m. bivittatus* the labials are separated from the eye by suboculars, lance-shaped mark on the head is distinct (even in adults) (Fig. 1), and the tongue is blue-black (Smith 1943; Daniel 2002; Whitaker and Captain 2004). Both the subspecies grows up to 6-8 m in length, occur in dense as well as in open grasslands or in rocky outcrops along rivers and *jheels* (Daniel 2002). They mostly feed on warm-blooded animals, such as birds and mammals. *Python molurus* has a wide distribution in India (Smith 1943; Daniel 2002; Bhupathy 1995; Whitaker and Captain 2004). Though confirmed distributional records of *P.m. bivittatus* from India are sketchy, confirmed reports are available from North-east, Orissa (Bhitarkanika Wildlife Sanctuary) and Uttarakhand (Rajaji National Park) (Bhupathy 1995).

Two consecutive observations of adult *P.m. bivittatus* were made in the Corbett Tiger Reserve (29° 25'-29° 40' N; 78° 5'-79° 5' E) in Uttarakhand, India. The first observation was made on December 28, 2004 in the grasslands (locally called *chaur*) of Dhara Range, and the other was made on June 19, 2006 near the Dhangari gate in the Dhikala Range. On both the instances, the identification features described by Smith (1943), Daniel (2002), and Whitaker and Captain (2004) fitted well. These observations constitute the first record from this protected area and form an additional locality record for this subspecies in northern India. Moreover, it forms an addition (at subspecies level) to the existing checklist of 22 species of snakes reported from the Reserve (Chopra 1979).

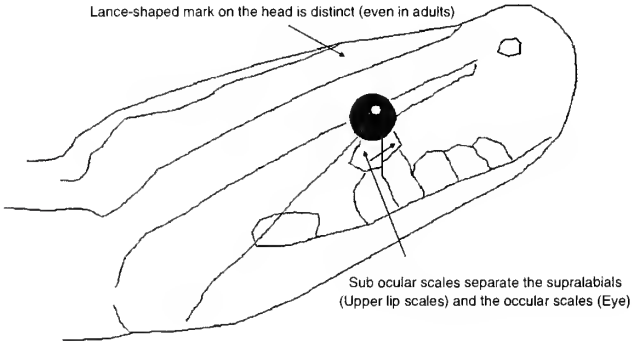

Fig. 1: Schematic diagram to illustrate the identifying features of the Burmese Python *Python molurus bivittatus*

It is worth noting that *P.m. molurus* and *P.m. bivittatus* occur sympatrically. Are they really subspecies or distinct species is yet to be determined based on DNA studies. How do they share the resources in their sympatric ranges if they are distinct species? Moreover, *P.m. bivittatus* is a Malayan faunal element, and there are a few recent records of species such as (1) Tree Frog *Chirixalus* sp. (2) Tricarinate Hill Turtle *Melanochelys tricarinata* and (3) Copper-head Ratsnake *Elaphe radiata* near Dehradun, Uttarakhand (Bhupathy 1995), knowledge on the extent of invasion of Malayan reptilian elements in India remains scanty and is largely based on old records by Smith (1943).

The Corbett Tiger Reserve forms an important repository of the natural heritage of Uttarakhand and is one of the best-protected areas of the Sal forest in Siwalik ranges, perhaps the last refuge of a number of threatened animal species in the Himalayan Bhabar tract.

ACKNOWLEDGEMENTS

The observations were made during the Study on Ecology of Otters in Corbett Tiger Reserve: Impact of Kalagarh reservoir on habitat use pattern. We wish to place on record our indebtedness to the Forest Department, Uttarakhand; Director, Wildlife Institute of India, Dehradun and Dr. S.A. Hussain, Principal Investigator of the Project. We are grateful to Romulus Whitaker and Ashok Captain for helping us identify the photographs and Dr. Subramanian Bhupathy (SACON-Coimbatore) reviewed the manuscript. We express our sincere gratitude to Dr. Asad R. Rahmani, Director, BNHS for his encouragement and valuable comments on the manuscript. The kind help rendered by our colleagues: Dr. Basudev Tripathy and Ishan Agarwal (Wildlife Institute of India, Dehradun)

and Dr. Parikshit Gaumtam & Dr. S.K. Behera (WWF-India) is highly appreciated. The first author acknowledges the Council of Scientific and Industrial Research (HRD Group), New Delhi for awarding a research grant.

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11. REDESCRIPTION OF *GARRA ABHOYAI* HORA (TELEOSTEI: CYPRINIDAE: GARRINAE) WITH A NOTE ON *GARRA RUPECULA* FROM MANIPUR, INDIA[1]

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Introduction:

Fishes of the genus *Garra* Hamilton inhabit bottoms of fast flowing streams and are widely distributed from southern China, across South-east Asia, India and the Middle East to northern and central Africa (Kullander and Fang 2004). The genus is characteristic in having its mouth and its posterior region highly modified into a suctorial disc, also called mental disc.

McClelland (1839) described *Gonorhynchus rupeculus* from Mishmi Hills, Arunachal Pradesh (Brahmaputra basin), India. Gunther (1868) and Day (1878) considered the species a synonym of *Discognathus lamta* (Hamilton). Hora (1921) described *Garra abhoyai* from the streams of Ukhrul district of Manipur (Chindwin basin). Menon (1964), while revising the genus, considered McClelland's (1839) species as valid and redescribed it as *Garra rupecula*, based on specimens only from Chindwin basin in Manipur, an entirely different basin from the type locality. He also considered *Garra abhoyai*, a synonym of *Gonorhynchus rupecula*. Vishwanath (1993) and Vishwanath and Joyshree (2005) also followed earlier literature in treating the validity of *Garra rupecula* of Manipur.

In the present study, several specimens of *Garra*, confirming the description of Hora's (1921) *G. abhoyai* were collected from the hill streams in the Ukhrul and Imphal west districts of the State. The species is considered valid and redescribed here. The status of *G. rupecula* of Manipur is also discussed.

Measurements and counts follow Kullander and Fang (2004), and that of head depth follow Menon (1964). Scale counts follow Kottelat (2001). Specimens examined for the study are deposited in the Manipur University Museum of Fishes (MUMF). Number in parentheses after a particular count indicates number of specimens examined.

Garra abhoyai Hora

(Figs 1-3)

Garra abhoyai Hora 1921: 664 (type locality Naga Hills, Ukhrul district, Manipur).

Material Examined: MUMF 6296-6305, 10, 49.3-54.90 mm SL, Iril R. at Phungdhar, Manipur, 17.i.2003, K. Nebeshwar, M. Shantakumar and I. Linthoingambi, MUMF 8048-8054 and 8103-8112, 17, 45.0-53.0 mm SL, Nambul R. at Singda, Manipur, 3.xi. 2005, H. Joyshree.

Diagnosis: A small species of *Garra* with smoothly rounded snout tip; rostral lobe absent; proboscis absent; predorsal scales present but those towards head very reduced, irregularly arranged and covered by mucus almost making it appear to be absent; chest and abdominal region naked, however, area just in front of pelvic fin scales covered by mucus; papilliferous tissue absent along the upper jaw; papillations present at an angle of upper and lower lip; lateral line scales 30-33 + 1-3.

Description: General appearance as in Fig. 1. Table 1 presents morphometric data. Body small, maximum standard length 58.7 mm, elongated, predorsal contour straight; body depth almost uniform; ventral aspect flattened from head to anal fin base; snout rounded without transverse groove,

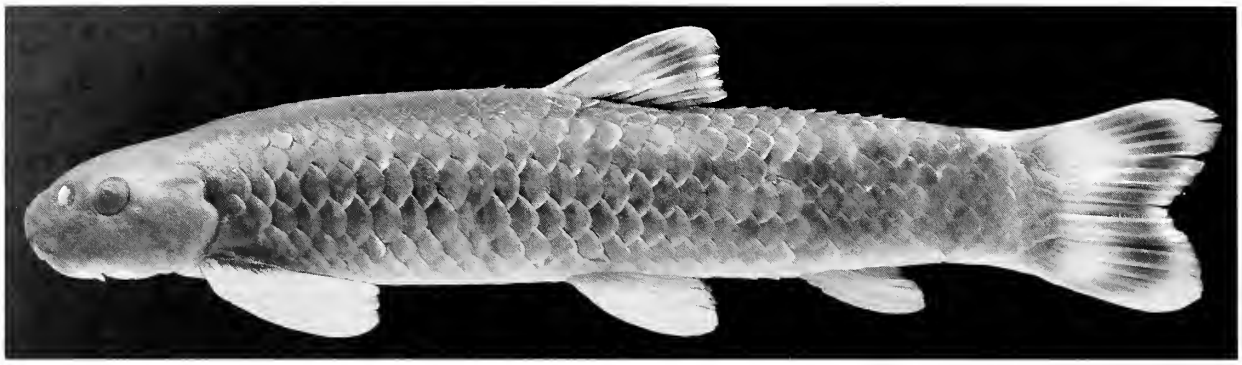

Fig. 1: Lateral view of *Garra abhoyai*

proboscis absent; rostral lobe absent; head wider than deep, orbit in mid HL. Anterior barbel not reaching margin of rostral cap. Central pad oval shaped, wider than long. No papilliferous tissue along the upper jaw. Papillations present at an angle of upper and lower lip. Caudal peduncle short almost as deep as long.

Fins: Dorsal fin origin equidistant between anterior margin of eye and caudal fin base, posterior margin straight, bearing ii, 6, i rays, posterior end at same level with that of pelvic fin. Pectoral fin with round posterior margin, bearing i, 13 rays, fourth branched ray longest extending halfway the distance between its anterior base and pelvic fin. Pelvic fin origin at vertical level of 2nd branched ray of dorsal fin, round posterior margin, bearing i, 7, i rays, 2nd and 3rd branched ray longest, fin extending to vent. Anal fin short but extends beyond mid of caudal peduncle, straight posterior margin, bearing ii, 4, i rays. Caudal fin emarginated, bearing 9+8 rays.

Table 1: Morphometric data of *Garra abhoyai* Hora

Characters	Mean	Range	S.D.
Standard length (mm)		39.1-58.7	
Percentage Standard length			
Body depth (at dorsal)	18.2	17.6-18.7	0.4
Body depth (at anal)	16.0	15.6-16.7	0.3
Head length	22.7	22.0-23.5	0.5
Body width (at dorsal)	16.1	15.6-17.1	0.6
Caudal peduncle length	14.7	13.5-16.0	1.0
Dorsal fin length	12.3	11.5-14.2	0.9
Pectoral fin length	20.6	20.0-21.5	0.6
Pelvic fin length	17.0	16.2-18.0	0.6
Anal fin length	06.9	06.3-08.1	0.6
Predorsal length	53.7	51.4-55.0	1.2
Prepelvic length	56.8	54.4-59.0	1.6
Preanal length	79.8	78.0-81.2	1.3
Percentage Head length			
Head depth at nape	59.4	57.0-64.1	2.1
Head depth at eye	49.5	48.0-55.3	2.0
Head width at occiput	80.2	78.0-83.0	1.9
Snout length	45.5	44.0-48.0	2.3
Eye diameter	19.3	17.3-20.4	1.4
Interorbital width	52.2	49.2-56.0	2.5
Internarial space	40.3	38.3-42.0	1.5
Disc length	35.5	33.0-38.1	2.2
Disc length% its width	73.0	70.5-76.2	2.3
Central pad length% its width	71.7	69.4-75.0	2.5

Scales: Predorsal region appears to be naked due to thick mucous cover (Fig. 3a). On scraping, it is observed that scale boundaries are not well distinguished, becoming much reduced and irregularly arranged (Fig. 3b). Chest and abdominal region naked, however area just in front of pelvic fin has scales covered by mucus (Fig. 2). Scales behind dorsal fin up to caudal fin base distinct with well defined margins, 11-14 [11(5), 12(6), 13(8), 14(8)] in number. However, in larger specimens 45.7 mm SL onwards, scales just behind dorsal fin tend to be reduced and irregularly arranged. Lateral line 30-33 + 1-3, i.e. 30(4), 32(7), 33(16) + 1(5), 2(17), 3(5). Scales between dorsal fin base and lateral line ½ 4 and that between lateral line and pelvic fin base 4½. Circumpeduncular scales 16.

Colour: Greenish brown on back, paler ventrally. Dorsal fin with a submarginal black band, band present only on the rays. Caudal fin with a distinct W-shaped black band.

Distribution: INDIA: Manipur: Iril R., Nambul R. (Chindwin Basin).

Discussion: Specimens of *Garra* from Iril and Nambul rivers under study agree with the original description of *G. abhoyai* Hora. In the identification of *Garra* spp., lepidosis has been considered as an important character. Hora (1921) reported that in the above species, the scales on the sides and postdorsal region were well marked while those in front of the dorsal were reduced and appeared to be almost devoid of scales to the naked eye. Similar observations were also made in the present study.

Garra abhoyai is distinguished from *G. lissorhynchus* in having the angle of upper and lower lips papillated vs. ridged; predorsal scales reduced and irregular vs. well defined; scales between lateral line and pelvic fin base ½ 4 vs. ½ 3; anal fin rays ii, 4, i vs. i, 4.

McClelland (1839) described *Gonorhynchus rupeculus* from Mishmi Hills, Arunachal Pradesh (Brahmaputra basin), India. Gunther (1868) and Day (1878) considered the species

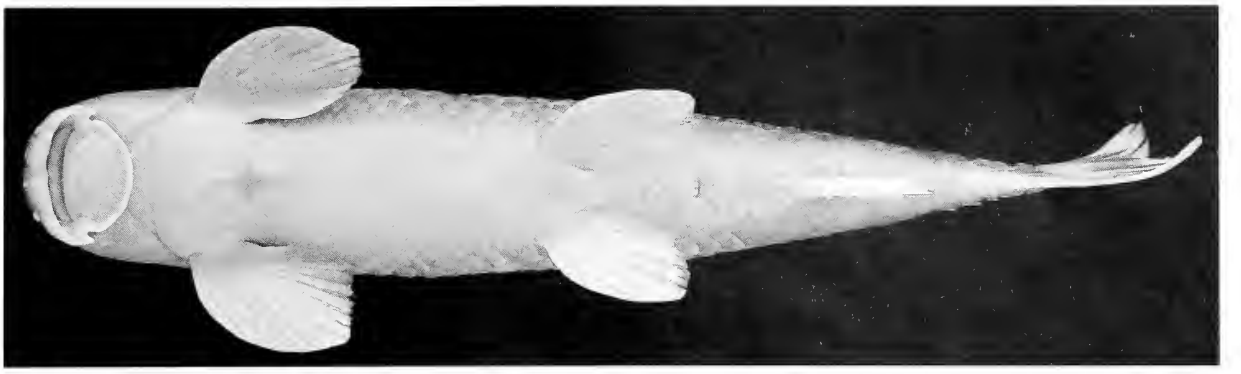

Fig. 2: Ventral view of *Garra abhoyai*

a synonym of *Garra lamta* (Hamilton), a species with no wavy or W-shaped black bar across the caudal fin. The species does not occur in Chindwin basin. Hora (1921) considered McClelland's species as *Garra rupeculus* based on examination of specimens of maximum 2 inches length from the hill streams of Manipur valley (Chindwin basin), an entirely different drainage from the type locality. The important characters he observed in the fish are: a light black streak near the free margin of the dorsal, a deep black bar across the base of dorsal and a wavy band in the middle of caudal fin; rows of open pores on snout extending to lateral line; origin of dorsal slightly nearer to caudal base than to tip of snout; ventral fin extends beyond anus and ventral surface naked.

G. abhoyai can be easily distinguished from *G. rupecula* in having clear W-shaped black band marking on the caudal fin (Hora 1921). Thus, *G. abhoyai* is resurrected from the synonymy of *G. rupecula*.

Hora's (1921) *Garra rupecula* from Manipur shares similar characters with *G. nambulica* Vishwanath and Joyshree (2005) in having open pores on snout continuing with lateral line, black bands across dorsal and caudal fins, and absence of scales on ventral surface. It is also similar to *G. paralissorhynchus* Vishwanath and Shanta (2005) in having similar types of colour bands on dorsal and caudal fins also. His descriptions were based probably on a mixture of small specimens (29.7-34.4 mm TL) of both the latter two species.

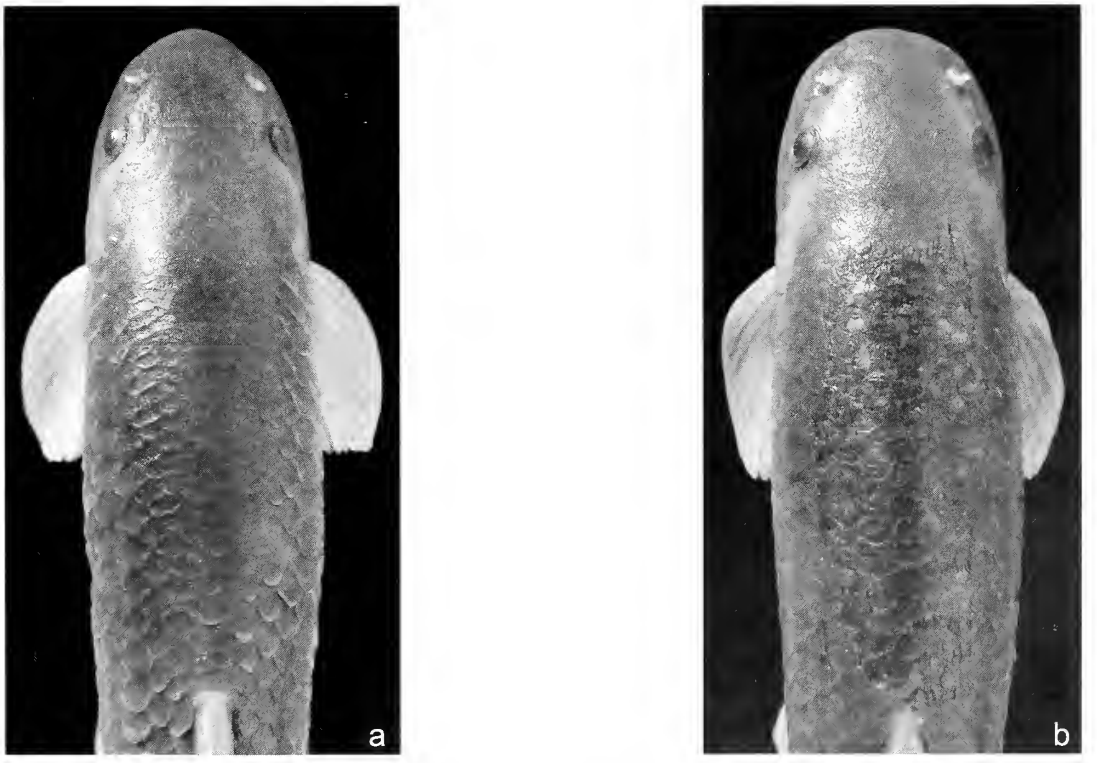

Fig. 3: Dorsal view of *Garra abhoyai*:
a. showing mucous covered predorsal region; b. predorsal region after scrapping mucous

Decisions in fish taxonomy of earlier days were often based on a few samples of very dissimilar sizes and poorly preserved as a result of the logistical problems and difficult technical conditions of field work at that time. Authors often observed variability, but the available material did not allow them to conclude whether the variability was ontogenic, geographic, intra- or interspecific; and with the then prevailing species concepts it was usually conservatively concluded for intraspecific variability (Ng and Kottelat 2000).

The present concept is that fresh water fishes are distributed in a particular river basin and their congeners in an entirely separated different basin are proved to be different species. Various revisional studies of 'such highly variable' and widely distributed forms of earlier days have now shown to be aggregates of distinct, often not even closely related species (Kottelat and Lim 1993; Kottelat 1996; Roberts and Ferraris 1998; Ferraris and Runge 1999; Ng and Kottelat 2000; Ng 2003; Chakrabarty and Ng 2005).

Thus, the distribution of *Garra rupecula* in the Chindwin basin of Manipur may be considered invalid with the validation of *G. abhoyai.*

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12. NATURAL HISTORY AND EARLY STAGES OF THE WESTERN GHATS ENDEMIC GOLDEN FLITTER *QUEDARA BASIFLAVA* (HESPERIIDAE, LEPIDOPTERA) FROM SOUTH-WESTERN INDIA[1]

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The genus *Quedara* Swinhoe, 1919 (Family Hesperiidae, Lepidoptera) has five species, which are distributed from southern India to Borneo and Sumatra in South-east Asia. The genus is represented by a single species in the Western Ghats, south-western India: the Golden Flitter *Quedara* (=*Hyarotis*) *basiflava* de Nicéville. The genus is allied to *Hyarotis*, which has two representatives in the Western Ghats: the Tree Flitter *H. adrastus* Stoll and the Brush

Flitter *H.* (=*Kineta*) *microstictum* Wood-Mason & de Nicéville. Early stages of *H. adrastus* were described by Bell (1927), but those of *H. microstictum* and *Q. basiflava* have so far been unknown. Nothing is known about *Q. basiflava* apart from its taxonomic status, and this is the first report of the natural history and early stages of the species.

This article is based on work carried out mainly in the Karian and Varagaliar sholas in the Anamalai Hills (10° 13'-10° 31' N; 76° 52'-77° 23' E) over eight months (November 1998-May 1999, and additional field work during 1999-2001). During this period I successfully reared nine adults from first or second instar caterpillars, and observed more than 500 caterpillars. The natural history of this species has also been studied in recent years in Ponmudi-Kallar Valley and in Arippa and Schendurni wildlife sanctuaries (WLS) near Thiruvananthapuram, Kerala, by C. Susanth, B.V. Premkrishnan, S. Kalesh and Satya Prakash. Their observations, if different from mine in the Anamalai Hills, are also reported below.

Status and distribution: The species is narrowly endemic to the Western Ghats. It occurs south of Coorg up to the southern tip of the Western Ghats, both north and south of the Palghat Gap, on the eastern as well as the western slopes. It is most common in the Anamalai Hills southwards up to Arippa and Schendurni WLS in Kerala. It has always been considered a very rare species and some of the earlier authors had missed it south of the Palghat Gap (Evans 1910, 1932; Ugarte and Rodricks 1960; Larsen 1988). However, judging from the abundance of the caterpillars, I propose that the species is actually common in its habitat, but, as described below, the adults are rarely seen possibly because of their habits. The exception is the Rosemala area of Schendurni WLS, where adults are seen in fair numbers (C. Susanth pers. comm.).

Habitat: The habitat described here is only for caterpillars because adults were seen rarely. In the Anamalai Hills the host plants were various species of canes (*Calamus* spp.); hence, the caterpillars were commonly seen in dense evergreen forest patches as well as close to small natural openings and around forest paths, but not in large man-made openings. They were found between 500 and 1,400 m above msl although the numbers declined significantly above 900 m. The occurrence of the species in the Grass Hills and Eravikulam national parks, and in small forest fragments in the Akkamalai area close to Valparai, was confirmed by sightings of a few caterpillars and indirect evidence, such as bite marks (and characteristic leaf damage) and cells made on the host plants by the caterpillars. However, at these high elevations (>1,100m) they were uncommon even when at low- and mid-elevation evergreen forests I found dozens of caterpillars on single cane plants, and presence on a high proportion of individual plants.

Breeding season: Breeding was continuous throughout the year, but peaked from October to February in the Anamalai Hills and from June to August in Schendurni WLS (C. Susanth pers. comm. for Schendurni WLS). There were two brief lulls in breeding activity, one during March-April and the other during August-September. It is not known whether these periods were spent in egg, caterpillar or pupal stage. One caterpillar stayed dormant in captivity for three months from August to October and pupated at the end of it, but the length of the pupal stage was normal (C. Susanth pers. comm.).

Host plants: Three species of cane were identified on which caterpillars were seen for many months: *Calamus pseudo-tenuis* Beccari ex Beccari & Hook, *C. rotang* Beccari ex Beccari & Hook and *C. thwaitesii* Beccari ex Beccari & Hook (Arecaceae). Whether any of these cane species is preferred over others is still unknown.

Eggs: The eggs were faintly shiny white and dome-shaped with vertical ribs, but their detailed structure was not studied. They were laid in batches of 2-13 eggs (5.9 ±2.9, N = 20 clutches), mostly on the underside of *Calamus* leaves. The eggs were laid in one or two rows, touching each other, mostly on fresh leaves, but a few were on older leaves, which were later eaten by the caterpillars. I did not notice a preference for *Calamus* in shaded or open areas: the caterpillar density seemed equal on plants inside the forest or near natural forest edges and on forest paths.

Caterpillars: The caterpillar was white with a light reddish-brown head (Fig. 1a). There were three pairs of markings on the face: the first pair – large, tear-shaped, sharply defined prominent yellow markings above the mandibles with yellowish area in between, the second pair – much smaller and faint yellow spots above the first pair, and the third pair – faint whitish-yellow markings above the second pair of markings, close to the top of the head (Fig. 1b). The mandibles were darker in colour, almost chocolate-brown, and the eyes were initially brown but turned white in later instars. The sides and the back of the head, towards the second segment, were darker reddish brown or almost black. The head of the recently moulted caterpillar was light green with the yellowish markings paler; the markings darkened within a few hours. The coloration of the caterpillar remained unchanged throughout, except for markings on the head that became progressively more prominent in successive instars. The head had a distinct groove on top. The anal flap was rounded, prominent and covered with fine white hair. Approximately three days before pupation a pair of white lines appeared on the back of the caterpillar. These lines were a continuation of the two white bars present on the anal flap of the caterpillar throughout its life.

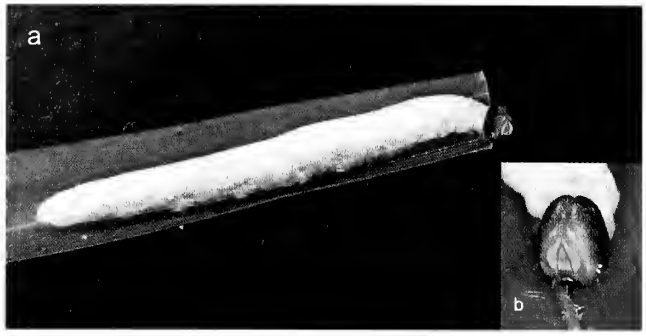

Fig. 1a: Caterpillar of *Quedara basiflava*;
1b: close-up of the head

Fig. 2: Cells made by the first instar larvae

Fig. 3: Cells made by third to fifth instar larvae

The caterpillars dispersed immediately after consuming their eggshells. Each caterpillar occupied an entire leaflet to make its cell and feed, and caterpillars from the same clutch occupied adjacent leaflets. Early larval cells were small (*c.* 2-4 cm in length) and made in the middle of the leaf margin. These were simple tubes made by turning the leaf margin downwards and holding it in place by silk threads (Fig. 2).

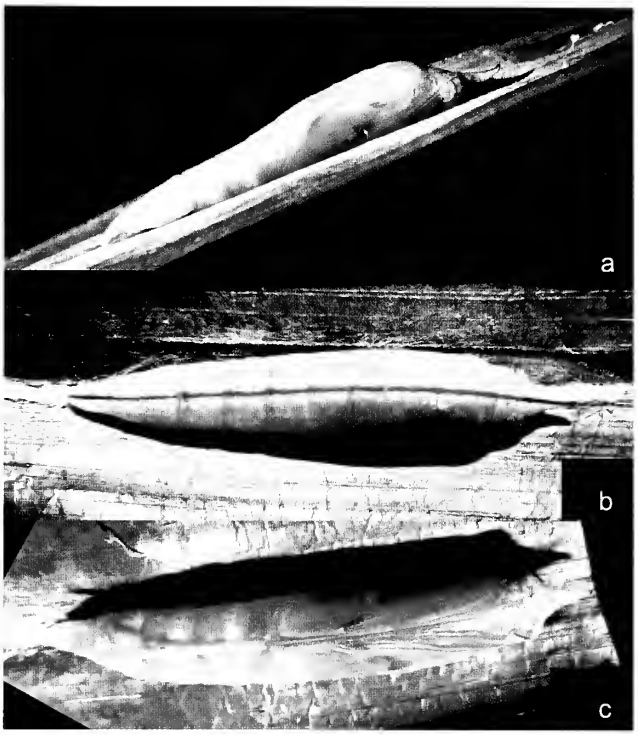

Fig. 4: Pupa of *Q. basiflava* a day before eclosion, showing change in wing coloration
a: lateral view; b: dorsal view; c: ventral view

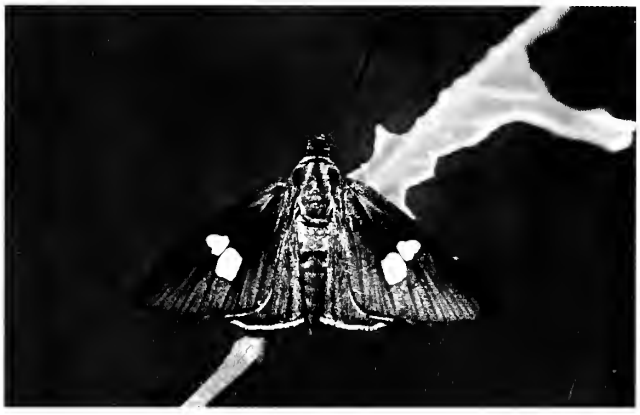

Fig. 5: Freshly eclosed *Q. basiflava* drying its wings

Fig. 6: Underside of freshly eclosed *Q. basiflava*

After the second instar, caterpillars made larger cells by putting the two margins of a leaf together, bending the leaf longitudinally at the midrib (Fig. 3). The caterpillars consumed portions of the leaf between their resting spots inside the cells and the terminal portions of the leaf, usually leaving the midribs and edges of leaves intact, which produced characteristic leaf damage. This characteristic pattern allowed distinguishing between the leaf damage caused by this species and that by other sympatric *Calamus*-feeding species: the Common Palmfly *Elymnias hypermnestra* Linnaeus and the Giant Redeye *Gangara thyrsis* Fabricius that damaged the leaves more extensively, and the Maculate Lancer *Salanoemia sala* Hewitson that did not leave the leaf margins intact, and had more elaborate cells.

The caterpillars stayed stretched on the roof of the cells, their heads pointing towards the leaf apex, without turning their heads on their sides, as many hesperiids do. They fed mainly at dusk and at night. The frass pellets, which were considerably dry, were shot away with force, and so the cells and surroundings were always clean. The caterpillars were shy, and their movements were slow. They made very thick mats of silk to line their larval and pupal cells, which remained bright white and quite conspicuous for many months after they had been abandoned. Just before pupation, caterpillars discharged light brown rather than greenish droppings. The total length of the caterpillar, just before pupation, was 40 mm.

Pupae: Pupae were pale green and slender, with a pointed projection at the anterior end and the proboscis running free beyond the wing cases almost up to the tip of the abdomen (Figs 4a,b,c). There was a brown longitudinal line on the dorsal side of the pupa. Unlike many southern Indian hesperiids (e.g. *G. thyrsis* Fabricius and the Common Banded Awl *Hasora chromus* Cramer (Kunte 2000)), pupae of this species did not form cereus powder.

The caterpillars always wandered off before pupation, so the pupae were never found on the host plant. Pupal cells were probably formed close to the ground on other plants or among the leaf-litter as in spite of extensive searching pupal cells could not be located. The pupal cells made by caterpillars that were confined to host plant twigs, using mosquito netting, were structurally similar to the larval cells of late instars.

Pupae were 30 mm long, with a maximum circumference of 6 mm. The average pupation period was 13-15 days, and the adults always eclosed during the early half of the day, between 0800 and 1300 hrs.

Morphometric measurements: Morphometric measurements were taken (in millimetres) with callipers on two newly emerged specimens (Table 1).

Imago: Although caterpillars were abundant, I saw only two adults in nature. Whether they were crepuscular or inhabited some microhabitat that was mostly inaccessible to human observers, such as the canopy of tall evergreen forests, is still unknown (although no adults were seen during canopy observations totalling approximately 30 hours). On May 12, 1999, at 1415 hrs, I saw an old specimen – the colours had faded and scales had been lost, but the wings were not torn – in a small clearing in Karian shola. It was sunny, but light penetrated to the forest floor in stray beams. The butterfly was perched on the upper side of a leaf, 1 m off the ground, in a partly shaded part of a sapling. It was basking in the usual hesperiid fashion – hindwings spread flat, forewings at an angle. Its flight was similar to that of the Common Banded Demon *Notocrypta curvifascia* Felder and Felder, a sympatric hesperiid. In fact, this species may be confused with *N. curvifascia* when it is basking when the underside of the wings is not visible because the markings on the upperside of their forewings are similar particularly from a distance.

The newly eclosed adults dried their wings while spreading them in the fashion of a noctuid moth, forewings covering the hindwings (Fig. 5), but otherwise they kept the wings closed, revealing the characteristic yellow base of the chocolate-brown hindwings (Fig. 6).

Parasitoids: Bell (1927) noted that parasitism by parasitoid wasps seemed to be a big factor contributing to mortality in the early stages of a related species, *H. adrastus*, in which up to 80% of the eggs and caterpillars were parasitised by Ichneumon wasps. However, parasitism on *Q. basiflava* was not significant; none of the caterpillars that were observed were parasitized.

In this note I have presented the first detailed account of the natural history of this endemic hesperiid butterfly of the Western Ghats. However, early stages, habitat requirements, population and conservation status remain unknown for other Western Ghats endemic hesperiids such as the Coorg Forest Hopper *Arnetta mercara* Evans, the Sitala

Table 1: Morphometric measurements of adult *Quedara basiflava*

Body length	Thorax length	Thorax width	Wingspan	Proboscis length
17 mm	6 mm	4 mm	39 mm	24 mm
16 mm	6 mm	4 mm	39 mm	19 mm

Ace *Thoressa sitala* de Nicéville and the Evershed's Ace *T. evershedi* Evans, 1910. We cannot assess relevant conservation issues for these butterflies if we do not have any information about them. Considering the rapid habitat degradation and destruction that is taking place in the biologically diverse southern Western Ghats, I hope such basic information on these species will be available soon through a more collaborative effort from naturalists in southern India. This will ultimately help us protect these endemics and their habitats.

ACKNOWLEDGEMENTS

I thank V.V. Sivan for his help in identifying the host plants, and Deepa Agashe, Ramana Athreya, S. Kalesh, Satya Prakash and C. Susanth for comments on an earlier draft of the manuscript. Thanks are due to the Principal Chief Conservator of Forests (Tamil Nadu) for granting research permission, and to the local staff of the Forest Department at the Indira Gandhi National Park and Wildlife Sanctuary, the Anamalai Hills, for providing local permits and cooperation.

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13. RANGE EXTENSION OF THE WAVY MAPLET *CHERSONESIA INTERMEDIA* (NYMPHALIDAE, LEPIDOPTERA), FROM PAKKE TIGER RESERVE, ARUNACHAL PRADESH, INDIA[1]

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Tribe Cyrestini (Nymphalidae, Lepidoptera) is represented in India by two genera: (a) *Cyrestis* Boisduval, 1832, and (b) *Chersonesia* Distant, 1883; commonly known as Maps and Maplets. Of these, *Chersonesia* is highly restricted in distribution: *Chersonesia risa* (Doubleday, 1848), the Common Maplet, occurs in the Himalaya from Kumaon and Nepal eastward to north-east India, extending to Indo-China and south-east Asia (Smith 1989). *Chersonesia intermedia* Martin, 1895, the Wavy Maplet, is also distributed in Indo-China and south-east Asia, but is more restricted in India. It has been collected from Manipur and Naga Hills in north-east India and is reportedly very rare (Evans 1932; Wynter-Blyth 1957). Note that the subspecies of *C. intermedia* that occurs in NE India, i.e. *C.i. rahrioides* Moore, 1896, was previously treated under *C. rahria* (Evans 1932). *Chersonesia rahria* (Moore, 1858), as currently classified, does not occur in India.

On May 30, 2007 I photographed *C. intermedia* mud-puddling in a stream-bed running through the evergreen forest on the road to Khadi in Pakke Tiger Reserve in West Kameng district of Arunachal Pradesh. The species could be easily distinguished from *C. risa* in having: (a) the fifth line on the upper side of the wings reddish-brown and diffused, and (b) the sixth line from the wing-base curved and prominently angled near costa (Evans 1932; Wynter-Blyth 1957; Corbet and Pendlebury 1992; Pinratana and Eliot 1996). The fifth and sixth lines in *C. risa* are black, straight and of equal width, similar to the first four lines.

The precise localities from which *C. intermedia* was previously collected in Manipur are unknown but the sighting reported here comprises the first record of the species from Arunachal Pradesh and in the eastern Himalayas, at least 400 to 600 km away from the previously known distributional range of the species. It will be useful to find out whether the species also occurs in the Brahmaputra valley in Assam or whether it reaches Pakke only through the forested mountains of the south-eastern and northern Arunachal Pradesh.

The field trip on which this sighting was made was funded by the American Philosophical Society's Lewis and Clark Fund for Exploration and Field Research. Local arrangements made by Mr. Tana Tapi, DFO, Pakke TR, are gratefully acknowledged.

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14. INTRASPECIFIC COLOUR VARIATION IN SPIDER *PARAWIXIA DEHAANII* (DOLESCHALL) (ARANEIDAE; ARANEAE), A CASE STUDY IN SANJAY GANDHI NATIONAL PARK, BORIVLI, MUMBAI, MAHARASHTRA, INDIA[1]

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The Araneid genus *Parawixia* was raised by F.O.P. Cambridge in 1904 with the type species *P. deschricta* (F.O.P. Cambridge); the genus has a wide range of distribution in South America, Mexico, India, Malaysia and Japan. *P. dahaanii* (Doleschall) is the only known Indian species so far reported from Karnataka, West Bengal, Gujarat and Sikkim states. The present report is the first report from Maharashtra in Sanjay Gandhi National Park, Borivli, Mumbai. Recently, the species has been reported by about 15-16 female specimens almost in the same locality of SGNP. It was very surprising to note the different colour morphs among the same population of this species.

The broad identification characteristics of *Parawixia dehaanii* (Doleschall) total body size ranges between 18-22 mm in length, cephalothorax longer than wide, narrowing in front, typically clothed with white pubescence in middle portion, spines and hair with granular base on cephalic region elevated in the middle, forming a bulge just behind the ocular area, ocular quad slightly wider in front than behind and situated on elevation, lateral eyes nearly same in size, placed closely and situated at the base of horn-like tubercles; chelicerae strong, reddish-brown with moderate boss at the base; legs long and strong without band but darker on tarsi; abdomen triangular acutely pointed posteriorly and on anterior lateral spine like shoulder humps, five pairs of sigilla on dorsum arranged mid-longitudinally, epigynum with swollen base provided with stout, beak-like pointed , unwrinkled scape, bent at right angle with the base.

The described colour pattern shows chalk white transverse band extending between the pair of anterior lateral shoulder humps, dark brown on rest of the abdomen dorsum, ventrum grayish brown patches (Fig. 1a).

The female specimens recently collected at SGNP show four variants of abdominal colour pattern.

(1) Abdomen grayish with light brown tinge and a conspicuous 'V' like darker brown patch in the center of the abdomen giving more pointed appearance to the anterior lateral shoulder humps (Fig. 1b).

(2) Abdomen is completely light reddish brown with only two white dots between the anterior lateral shoulder humps. (Fig. 1c).

(3) Abdomen yellowish brown with some black patches in 'V' shape manner and rest of the abdomen blackish (Fig. 1d).

(4) Abdomen completely blackish brown without any markings (Fig. 1e).

The colour morphs in spider are known and have been discussed by different workers, unfortunately except Tikader, there are almost no authentic reports on such aspects from India. Tikader (1982) have reported as many as 18 colour morphs in *Neoscona mukerjai* (Tikader), a common colonial species in and around Pune city (Maharashtra). Campon (2001) reported colour variations in the colonial species *Parawixia bistriata*, he states that adult females are present in two distinct colour morphs (brown and yellow opisthosomes), which make the individuals cryptic on the substrates they are found during their solitary stage prior to oviposition; leaf substrates or on the branches and trunks of trees. His experiment showed that the yellow morph individuals exhibit substrates preference whereas the brown morph individuals do not.

Tikader (1982) has discussed the possible factors associated with colour variation in animals, such as (a) altitude, latitude and longitude, (b) climate, (c) rainfall,

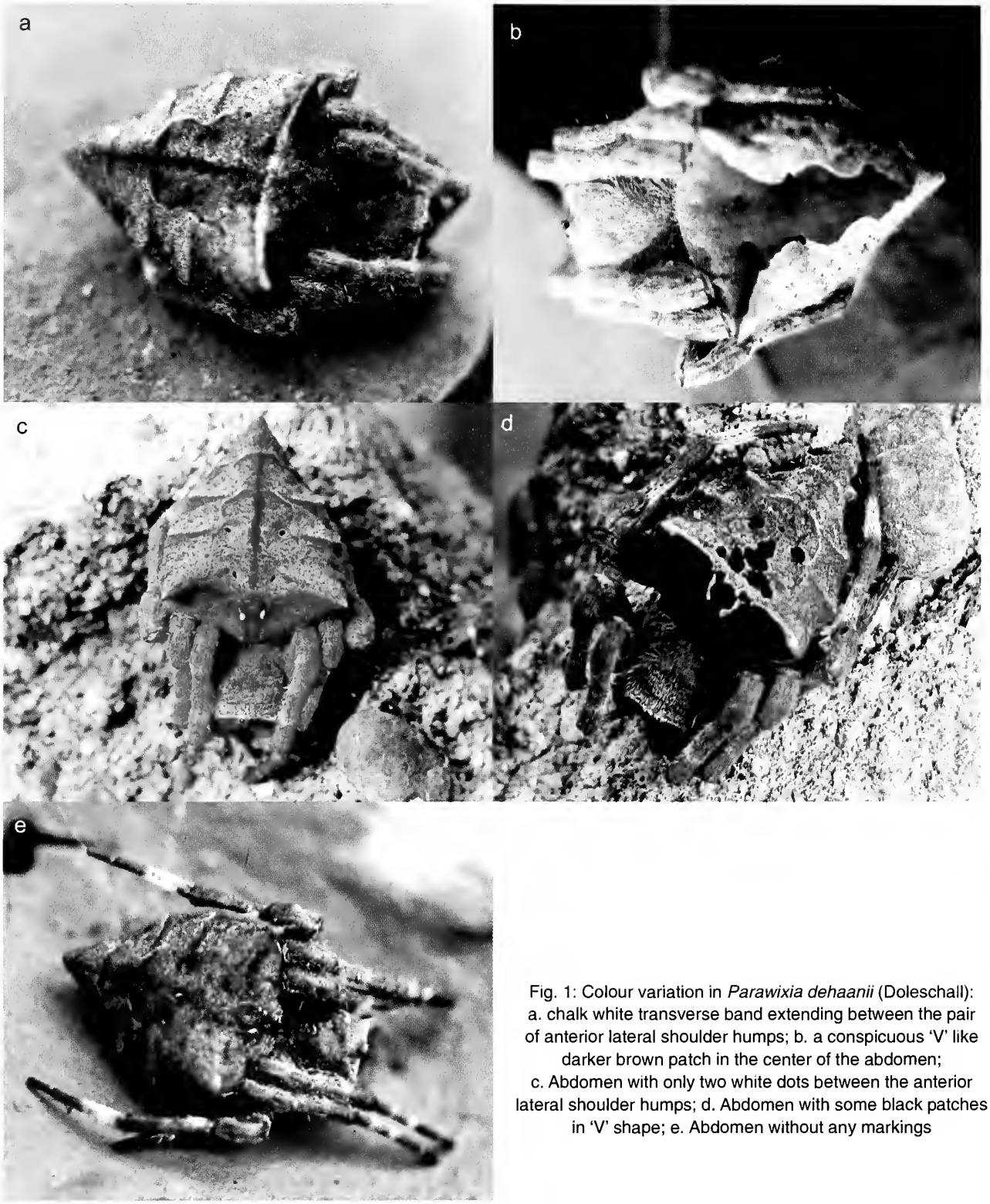

Fig. 1: Colour variation in *Parawixia dehaanii* (Doleschall): a. chalk white transverse band extending between the pair of anterior lateral shoulder humps; b. a conspicuous 'V' like darker brown patch in the center of the abdomen; c. Abdomen with only two white dots between the anterior lateral shoulder humps; d. Abdomen with some black patches in 'V' shape; e. Abdomen without any markings

surrounding, vegetation. Rainbow (1898) pointed out that spiders could change their colour according to the colour of flowers where they hide for hunting insect prey.

This is very common in *Thomisus* sp. (Crab spiders), but this is changeable colour form not fix colour patterns.

The spiders of the genus *Parawixia* are orb web weavers, and wait away from the web in a retreat made up of leaves of an inhabiting plant and fastened together with a silk thread, placed a little away above or on sides of the web. The spider may change its colour to camouflage the leaf

substrate or the branches and trunk of the tree. The present variant morphs of *Parawixia dehaanii* have been observed in the same population of the same locality, but were not communally colonized.

The authors are of the opinion that spiders being carnivorous animals, feed on various invertebrate biomasses which might have a role to play in the colour variation among the spider populations inhabiting the same macro-ecosystems.

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15. *BOTHRIOCHLOA INSCULPTA* (HOCHST.) A. CAMUS (POACEAE) – A NEW RECORD FOR RAJASTHAN[1]

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During a plant collection visit to Sadhuwali, Sriganganagar district, north-west Rajasthan, we collected *Bothriochloa insculpta* (Hochst.) A. Camus from the beds of IGC and nearby fields. A perusal of the literature shows that this species has hitherto not been reported from Rajasthan (Shetty and Singh 1987-93).

It is known so far from Madras (now Chennai) (Gamble 1967). The specimens have been deposited in the Herbarium, Department of Botany, Govt. Dungar College, Bikaner, Rajasthan. The identification of the species is based on Bor (1960).

Bothriochloa insculpta (Hochst.) A. Camus in Ann. Soc. Linn. Lyon, 1930, n.s. 76, 165 (1931) (Fig. 1). *Andropogon insculptus* Hochst. ex A. Rich. Tent. Fl. Abyss. 2, 458 (1851). *Amphilophis insculpta* (Hochst.) Stapf in Prain, Fl. Trop. Afr. 9, 176 (1917).

A stoloniferous perennial, 30-100 cm high. Sessile spikeletes shiny, shallowly grooved below the pit and glabrous, rarely with the margins finely hairy, pedicelled spikelets with one pit. It being scented and having a pit on one side of the seed hull. Leaves, stems and seed-heads are aromatic and aroma persists in stored hay.

Ecology: Fairly common in marshy and hilly habitats.

Specimen Examined: Near IGC, Sadhuwali, Sriganganagar. Sharma & Purohit DCH 671.

Fl. & Fr.: November-January.

We are grateful to Dr. R.P. Pandey, Senior Scientist, Botanical Survey of India, Port Blair for encouragement.

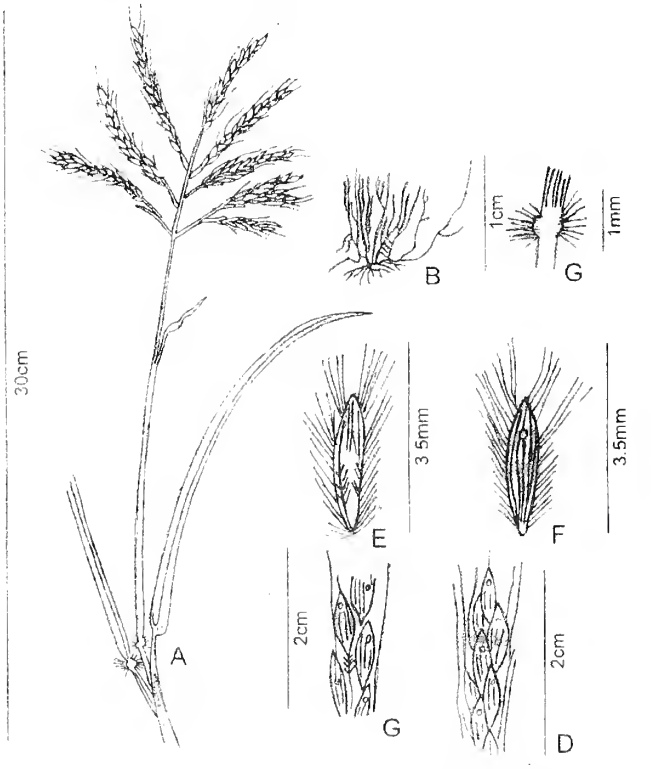

Fig. 1: *Bothriochloa insculpta* (Hochst.) A. Camus
A. Habit; B. Creeping Stem; C. Upper Sterile Spikelets; D. Lower Sterile Spikelets; E, F. Seed; G. Nose

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16. *ENTEROPOGON MONOSTACHYOS* (VAHL) K. SCHUM. EX ENGL. (POACEAE) – A NEW RECORD FOR RAJASTHAN[1]

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During one of the plant collection visits to Kailana lake, district Jodhpur, Rajasthan, we collected *Enteropogon monostachyos* (Vahl.) K. Schum. ex Engl. (Fig. 1) from a rocky area near the Lake. A perusal of the literature shows that this genus has not been reported from Rajasthan (Shetty and Singh 1987-93).

It is known so far from the states of Maharashtra and Tamil Nadu (Moulik 1997), India. The specimens have been deposited in the Herbarium, Department of Botany, Govt. Dungar College, Bikaner (Rajasthan). The identification of the species is based on Bor (1960).

Enteropogon monostachyos (Vahl.) K. Schum. ex Engl. in Abh. Preuss. Akad. Wiss. 17. 1894.

Cynosurus monostachyos Vahl, Sym. Bot. 2: 20. 1791.

Rottboellia pilosa Roth in Roem. et Schult, Syst. Veg. 2: 785. 1817.

Rottboellia triacatha Roth, Nov. Pl. Sp. 43. 1821.

Enteropogon badamicus Bhide in Journ. et Proc. Asiat. Soc. Beng.n.s. 7: 517. 1912.

Slender, Perennial grass; Inflorescence a solitary spike; Spikelets 2 flowered; Lower flower hermaphrodite; Upper male or barren; Glumes unequal, 1-3 nerved; Lemma awned, 3 nerved; Awns of the spikelets 8 mm long.

Fl. & Fr.: April-October.

Specimen Examined: Rocky Area, Near Kailana Lake, Jodhpur, Rajasthan. Purohit & Sharma, 3464.

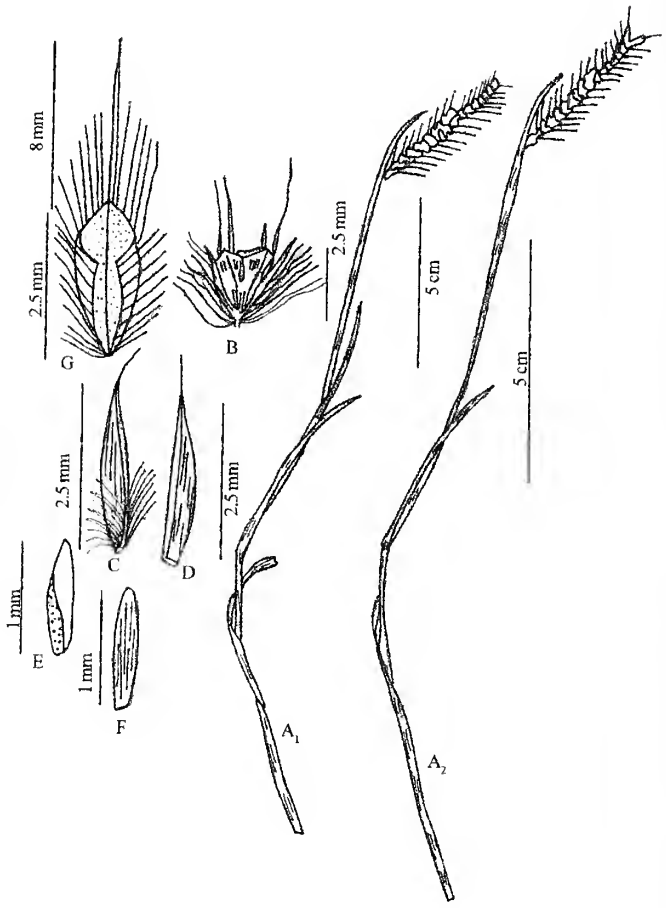

Fig. 1: *Enteropogon monostachyos* (Vahl.) K. Schumach ex Engl. A_1 & A_2. Plant; B. Spikelet; C & G. Lower Glume; D. Upper Glume; E. Palea; F. Grain

ACKNOWLEDGEMENT

We are grateful to Dr. R.P. Pandey, Senior Scientist, Botanical Survey of India, for encouragement.

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17. *POA SUPINA* SCHRAD. (POACEAE) – A NEW RECORD FOR RAJASTHAN[1]

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During one of the plant collection visits to Malcoat, district Sriganganagar, Rajasthan, we collected *Poa supina* Schrad. from a cultivated field. A perusal of the literature shows that this species has not been reported from Rajasthan (Shetty and Singh 1987-93).

It is known so far from Jammu-Kashmir and Himachal Pradesh, in India (Moulik 1997) and from Pakistan (Nasir and Ali 1982). The specimens have been deposited in the Herbarium, Department of Botany, Govt. Dungar College, Bikaner (Rajasthan). The identification of the species is based on Bor (1960).

Poa supina Schrad. Fl. Germ. 1:289; Nasir & Ali, Fl. of Pakistan, no. 143, 399. 1982; Bor, Grasses Burma Ceyl. Ind. Pak. 561. 1960; Moulik, Grasses and Bambusa of Ind. Vol.II, 533. 1997. *Poa annua* Linn. var. *supina* (Schrad.) Link, Hort. Berol. 1:181. 1827. *Poa ustulata* Frohner in Bot. Jb. 88: 437. 1968; Bor in Rech.f., Fl. Iran. 70:31. 1970.

Perennial, 18 cm high; Leaf blades flat; Ligule blunt, 1.5 mm long; Panicle pyramidal, 2-3 cm long; Spikelets 3.5 mm long; Glume 3.5 mm long; Lemma 3.5 mm long; Anthers 1.3 mm long.

Fl. & Fr.: October-February

Specimen Examined: Cultivated Field, Malcoat, Sriganganagar, Rajasthan. Purohit & Sharma, 3398.

We are grateful to Dr. R.P. Pandey, Senior Scientist, BSI Port Blair for encouragement.

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18. *CURCUMA YUNNANENSIS* N. LIU & S.J. CHEN (ZINGIBERACEAE) – A NEW RECORD FOR INDIA[1]

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Curcuma L. is a genus mainly from south-east Asia and represented by about 50 species in the world (Delin and Larsen 2000) and 23 species in India (Karthikeyan *et al.* 1989).

During an ethnobotanical plant survey in Jaintia hills of Meghalaya in 2002 some *Curcuma* rhizome were collected and planted in a garden; they flowered the next year. After critical analysis through literature (Delin and Larsen 2000; Baker 1890) it has been tentatively identified as *Curcuma yunnanensis* N. Liu & S.J. Chen, as the type material or any authentic specimen is not available for comparison. It is an endemic species of China (Delin and Larsen 2000), hitherto not reported from India.

A detailed description, illustration (Fig. 1) and relevant field data based on our own collection is given here to facilitate its easy identification in the field.

Curcuma yunnanensis N. Liu & S. J. Chen, Guihaia 7: 16. 1987; Delin & Larsen, Fl. China 24: 360. 2000.

Local name: Sying iong (Khasi).

Rhizomatous herb 1.3-2 m tall. Rhizomes globose 10 x 7 cm, strongly aromatic, creamish outside, pale yellow inside, with 2-3 sessile tubers, covered by membranous scales, root tubers absent. Pseudo stem to 35 cm tall, terete at base, flat above, brownish red. Leaves 5-6, distichous, petiolate, with

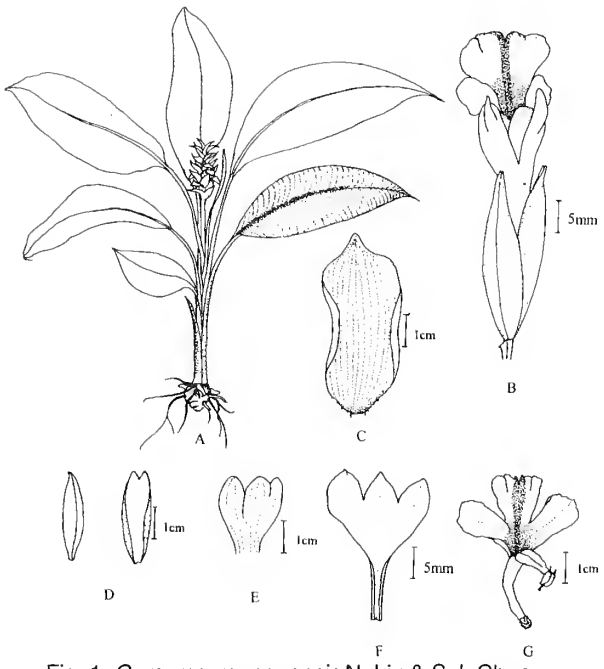

Fig. 1: *Curcuma yannanensis* N. Liu & S.J. Chen.
A. Habit (not in scale); B. Flower; C. Fertile Bract; D. Bracteole; E. Calyx; F. Sepals spread out; G. Labellum showing stamen and ovary

sheathing bases. Sheaths 29-35 cm long, brownish red, villous, margins white hairy, lower sheath bladeless. Petiole 8-30 cm long, glabrous, deeply channeled, green; blade 34-71 x 16-26 cm, oblong elliptic, acuminate, entire, glabrous, green with distinct reddish flush on upper 3/4th part along midrib. Spikes arise from center of the leaf sheath, 18 x 9.5 cm, greenish white; flowers usually 3 in each bract, pale yellow; peduncle to 22 cm long, 0.8 cm diameter, greenish white, terete, glabrous. Fertile bracts 4.2-5.7 x 2.8-3.2 cm, oblong, rounded, creamy white, glabrous, reflexed; comma bract 4-6; 5-6.2 x 1.1-2.5 cm, oblong-elliptic, narrowed at rounded apex, brightly creamy white, apex purple, glabrous; bracteoles 2; 2.8-3 x 1-1.4 cm, oblong-elliptic, boat-shaped, one keeled, apex shortly 2-lobed to inner one; lobe triangular 2.5 mm long, creamy white, glabrous; calyx tubular at base, unequally 3-lobed, 1-1.25 x 0.6-1 cm, creamish white, tube 7-9 mm long; lobe 2-3 mm long, triangular in outline, apex rounded, reddish tint outside, hirsute on outer surface; corolla tubular, 3.5-3.8 m long, 3-lobed at apex, tube 1.8-2 cm long, lobes 1.6 x 1.2 cm, triangular in outline, apex rounded, entire, deep purple, 6-nerved, glabrous; labellum tubular at base, 3-lobed, pale yellow with deep band from base to apex; tube 2.8-3.2 cm long, lateral lobes 1.5-1.7 x 0.8-1 cm, oblong, rounded apex, reflexed, creamy white, mid-lobe 2.1-2.3 x 1.6-1.8 cm oblong, rounded, reflexed, apex widen with 2 short lobules, margins entire, glabrous; fertile stamen 1, filament flat 1.5 x 0.6 cm, anther 2-lobed; each lobe 4-4.5 x 1-1.2 mm with 3 mm long spurred on both sides; ovary 2.5-3 x 2-2.5 mm, hairy, trilocular, white.

Fl.: July-August.

Distribution: INDIA: Meghalaya (Jaintia Hills); China.

Habitat: This species was found growing on moist shaded places, on slopes, along nullahs.

Specimen Examined: Samathi-108128, Nonjugi, Jaintia hills, 1,300 m, November 2002 (ASSAM).

Uses: Juice of rhizomes is taken for stomach pain and paste of rhizomes is applied to whole body as it is believed to destroy evil spirit.

ACKNOWLEDGEMENT

We are grateful to Dr. (Mrs.) S.J. Phukan, Deputy Director, Botanical Survey of India, Eastern Circle, Shillong, for providing necessary facilities and encouragement.

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19. *STYLOSANTHES FRUTICOSA* (RETZ.) ALSTON (PAPILIONACEAE) – A NEW RECORD FOR RAJASTHAN[1]

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During one of the plant collection visits to Degana tehsil, Nagaur district (Rajasthan), we collected *Stylosanthes fruticosa* (Retz.) Alston from the dry beds of Luni river and nearby fields. A perusal of literature shows that this genus has not been reported from Rajasthan (Shetty and Singh 1988-1999).

This paper records for the first time the occurrence of *Stylosanthes fruticosa* (Retz.) Alston from Rajasthan. It is known, so far, from the plains of Gujarat and Tamil Nadu (Matthew 1983). The specimens of *Stylosanthes fruticosa* collected from Alniyavas, Degana tehsil, Nagaur district have been housed in the Herbarium, Department of Botany, Government Dungar College, Bikaner, Rajasthan. The identification of the species is based on Matthew (1983).

Stylosanthes fruticosa (Retz.) Alston in Trimen, Fl. Ceylon 6 (suppl.): 77. 1931: Nooteb, Rainwardtia 5: 449. 1961; Verda, Kew Bull. 24: 59.1970; Matthew, III. Fl. Tamil Nadu Carnatic t. 224.1982.

Stylosanthes mucronata Willd., Sp. Ppl. 3: 166. 1802, nom. illegit.; Wight & Am. Prodr. fl. Ind. orient. 218. 1834; Hook f. Fl. Brit. India 2; 148.1876; Gamble. Fl. Madras 1: 326 (230). 1918; Matthew, Mat. Fl. Tamil Nadu Carnatic 198.1981.

Subshrub to 75 cm; branchlets appressed tomentose. Leaves trifoliate, to 1.5 cm; leaflets oblong-elliptic, 0.7-2.5 x 0.5-0.7 cm, chartaceous, prominently nerved, base subacute, margin ciliate, apex obtuse, stiff-mucronate; petiole to 8 mm; petiolule up to 1 mm; stipules 2 mm, adnate to petiole and sheathing. Flowers, 3-5 in terminal heads, sessile 4 mm across; primary bracts to 1.5 cm, bristly; secondary bracts to 6 mm; bracteoles 2. Receptacle 6 mm long, filiform, tomentose; upper 4 calyx-lobes subconnate, to 1 mm, ciliate; lower one lanceolate, 2 mm. Corolla yellow; petals shortly clawed, inserted at the throat of calyx-tube; standard orbicular, 6 mm, claw 6 mm; wings obovate, 4 mm, auriculate; keels oblong, incurved, 4.5 mm, apex obtuse. Staminal sheath 4 mm. Stamens monadelphous; filaments unequal, 1-2 mm; anthers dimorphic. Ovary subsessile; ovules 2 or 3; style filiform, 1 cm, glabrous; stigma minute. Pod oblong, 4 mm, beaked; strongly nerved; seeds reniform, 2 mm.

Flowers: November-January.

Pods: December-February.

Specimens Examined: Forest area. Near Luni river, Alniyavas, Nagaur district Rajasthan. Sharma & Aggarwal. 1236 (Dungar College Herbarium)

Distribution: Africa, Madagascar, Sri Lanka, India.

ACKNOWLEDGEMENTS

We are grateful to Dr. R.P. Pandey Scientist-C, Botanical Survey of India, Jodhpur, for encouragement. Thanks are also due to D.S.T. Jaipur for financial assistance.

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20. POLLINATION BIOLOGY OF THE ORCHID TREE *BAUHINIA VARIEGATA* L. (CAESALPINIACEAE) IN THE EASTERN GHATS, INDIA[1]

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The flowers of Caesalpiniaceae are less specialised than those of their counterpart members of Mimosaceae and Papilionaceae. They are open, usually with exposed pollen and nectar available to specialised and non-specialised pollen vectors (Hokche and Ramirez 1990). The species of Caesalpiniaceae exhibit a great variety of pollinating agents and mechanisms with an entomophilous trend (Arroyo 1981). The genus *Bauhinia* contains about 250 species distributed in the tropics of both hemispheres. It has 37 Indian species with flowers white, yellow and variegated red, and yellow. Vogel (1954) reported that *B. galpinii* and *B. mucronata* are sphingophilous in Africa, and Arroyo (1981) based on floral characteristics suggested that many other species of *Bauhinia* are probably sphingophilous. Hokche and Ramirez (1990) reported that pollination biology in neotropics is associated with the life form of *Bauhinia* species. Tree species *B. aculeata, B. multinervia, B. pauletia* and *B. ungulata* have large white flowers and produce more nectar with high sugar concentration. In *B. aculeata*, the nectar is sucrose rich, and in other species it is hexose rich; but all these tree species are mainly nocturnal and bat-pollinated. Fischer (1992) also reported bat-pollination in *B. ungulata*. Liana species, *B. glabra, B. guianensis* and *B. rutilans*, produce relatively small diurnal flowers with different colours and variations in form and colour of the upper petal; all these are pollinated by bees, wasps, butterflies and hummingbirds (Hokche and Ramirez 1990).

In India, Ali (1933) reported that *B. racemosa* and *B. purpurea* are bird-pollinated. Subba Reddi and Bhaskara Rao (1993) reported subsequently bees, wasps and butterflies that pollinate *B. purpurea*. The pollination biology of the other *Bauhinia* species has not been studied. *B. variegata* is a species of tropical and subtropical climates with hot dry summers and mild winters. It originated in the Eastern Asia in India and the Chinese provinces (CAB International 2000). Another source documented is a native to the northern India, Vietnam and south-eastern China (www.floridata.com). Hybridization between *B. variegata* and *B. purpurea* produces a naturally unstable sterile cultivar of horticultural value known as *B. blakeana* (Carol *et al.* 2005). The leaves, fruits, pods and exudates of *B. variegata* are edible by humans, and are consumed as a vegetable, and made into pickles and chutneys (CAB International 2000).

The plants of *Bauhinia variegata* at the Lotugedda-Lambasingi forest areas of the Eastern Ghats in Visakhapatnam district, Andhra Pradesh state, India were used for study during 2003-2005. As a deciduous tree, *B. variegata* sheds leaves prior to the flowering period, which falls during March-April. It produces large, colourful flowers in few-flowered panicles. The flowers are large, showy, fragrant, bisexual and zygomorphic. The sepals are green and irregularly lobed. The petals are 5, light purplish white; one petal is odd and 4.5 cm long with bright purple vertical streaks on the inner side. It is partly enveloped by a pair of 4.5 cm long lateral petals whose margins are in turn enclosed by a pair of 3.5 cm long anterior petals. The stamens are five, of which two are 4.5 cm long, one 4.4 cm and other two 3.8 cm; they are curved at the tip facing the odd petal. The anthers are dithecous and versatile in fixation. The style is long in some flowers and small in some others. In long-styled flowers, the style extends 1 cm beyond the anthers, and in small-styled flowers the style lies 1 cm below or almost equal to the level of the anthers. The style is curved at the tip and ends with a small filiform stigma. The ovary is green, flat, and monocarpellary with a single locule consisting of 12 to 14 ovules which arise on marginal placenta (Table 1).

The flowers open during early morning hours before sunrise and anthers dehisce after anthesis by longitudinal slits. The style and stigma curve upward. Nectar secretion occurs during late mature bud stage and centered at the flower base. The method of Dafni (1992) was used to measure nectar volume and Hand Sugar Refractometer to record nectar sugar concentration. A flower produces 7-10 µl of nectar with 30-32% sugar concentration in Day-1 flowers and 40-45% in Day-2 flowers. The corolla with stamens falls off on the 3rd day. Three hundred fresh flowers were tagged and followed to record natural fruit set rate. The fruits produced from these flowers were used to determine seed set rate. These flowers showed that natural pod set rate is 11% and seed set 82%. The pods mature within 3 weeks (Table 1). Each pod produces 2-11 seeds but 8-9 seeds form in most of the pods.

Bauhinia variegata shows the characteristics of melittophilous flowers as per Faegri and van der Pijl (1979). The most prominent characteristics are broad and distinct odd petal with nectar guide, lateral pairs of petals providing adequate platform for landing insects, and production of a small amount of nectar consisting of higher sugar concentration, fragrance and zygomorphic floral configuration. The study recorded bees (*Xylocopa latipes, X. pubescens, Ceratina simillima, Apis dorsata, A. cerana indica, A. florea* and *Trigona iridipennis*) and passerine birds (*Dicaeum erythrorhynchos, Nectarinia zeylonica, N. asiatica*, and *Zosterops palpebrosa*) as foragers of *B. variegata*. Fred (1976) stated that sucrose is the chief sugar in the flowers of most of the plant species. The flowers pollinated by long-tongued bees produce sucrose-rich or dominant nectar while those pollinated by short-tongued bees like *Xylocopa* species most often produce hexose-rich nectar. The long-tongued and short-tongued bees visit *B. variegata* flowers equally suggesting that the nectar of the latter may be a mixture of sucrose and hexose sugars, and enable bees to load nectar to a great extent. Barker and Lehner (1974a, b) also experimentally proved this with honeybees. The bees, *Xylocopa* species and *Apis dorsata* made frequent flights between individual plants to collect nectar; the later also for pollen, and so effect both self- and cross-pollination. All other bees stayed on the same plant for a long period to collect both pollen and nectar and in effect made infrequent flights between individual plants. Such a foraging behaviour results primarily in self-pollination. Although *B. variegata* is a potential pollen and nectar source for the bees, other co-occurring and simultaneously flowering plants, *Garuga pinnata* (Burseraceae), *Bauhinia racemosa* (Caesalpiniaceae), *Acacia sinuata* (Mimosaceae), *Gmelina arborea* (Verbenaceae), *Alangium salviifolium* (Alangiaceae) and *Careya arborea* (Lecythidaceae) attract them to different levels. Their attraction depends on the number of individuals of each of these plant species, their flower density and standing forage crop. The plant species such as *Acacia sinuata, G. arborea, Alangium salviifolium* and *C. arborea* have been reported to be pollinated by these bees and birds, and the last species also by bats (Solomon Raju and Rao 2002, 2006; Solomon Raju *et al.* 2004; 2005). Therefore, melittophily does not ensure reproductive success in *B. variegata* in the presence of other species that flower and provide ample forage simultaneously to bees in the habitat. It is in this context, the foraging activity of passerine birds observed assumes importance to promote pollinate rate, especially cross pollination.

Table 1: Floral characteristics of *Bauhinia variegata*

Parameter	Observation
Inflorescence type	Panicle
Flower color	Purplish white
Flower shape	Caesalpiniaceous
Time of anthesis	Early morning hours
Time of anther dehiscence (n = 50 flowers)	Immediately after anthesis
Mode of anther dehiscence	Longitudinal slits
Nectar volume per flower (n = 15 flowers)	8.5 ± 1.25 µl
Nectar sugar concentration (n = 20 flowers)	30-32% in Day-1 flowers; 40-45% in Day-2 flowers
Flower lifespan (n = 15 flowers)	3 days
Pollinators (n = 67 hours)	**Bees** *Xylocopa latipes* *X. pubescens* *Ceratina simillima* *Apis dorsata* *A. cerana indica* *A. florea* *Trigona iridipennis* **Passerine birds** *Dicaeum erythrorhynchos* *Nectarinia zeylonica* *N. asiatica* *Zosterops palpebrosa*
Natural pod set (n = 500 flowers)	11 %
Natural seed set (n = 500 flowers)	82%
Pod maturation time (n = 20 pods)	Three weeks

Bird flowers are usually red and the birds use them as an excellent signal of a high calorific reward, but they do not have intrinsic preference for red flowers (Raven 1972). In the genus *Bauhinia*, insects and hummingbirds pollinate *B. glabra, B. guianensis* and *B. rutilans* which produce variously coloured upper petal (Hokche and Ramirez 1990). In the present study also, bees and passerine birds pollinated *B. variegata*. The odd upper petal seems to be the main attractant for birds to pay visits to flowers. The birds prefer concentrated sugar solution to dilute solution but bird flowers characteristically produce less concentrated nectar to discourage unwanted flowers (Bolten and Feinsinger 1978). *B. variegata* flowers produce nectar with high sugar concentration and the nectar is expected to be a mixture of sucrose and hexose sugars in almost equal proportions; this characteristic is important for birds to visit them. The birds observed probe the flowers from the front to collect nectar and effect pollination. As birds are far flying, they promote cross-pollination in their search for nectar on different trees located in an area and in different areas to quench their thirst. The bird species mentioned above, utilized *B. variegata* as nectar source consistently until exhausted. They foraged throughout the day with more activity during forenoon. They landed on the flowering branch and approached the flowers slowly to insert their bill into the flower base for sucking nectar. In doing so, the bill, forehead and throat of the birds contacted the stigma first and later the anthers in long-styled flowers and both sex organs contacted almost simultaneously in small-styled flowers. As the nectar produced per flower is small in quantity, the birds visited different individuals in quest of more nectar effecting both self- and cross-pollination. Ali (1933) reported that *Nectarinia asiatica* and *N. zeylonica* pollinate purplish white flowers of *B. purpurea* and whitish-yellow flowers of *B. racemosa* in the Western Ghats of India. Subba Reddi and Bhaskara Rao (1993) later reported that different insects pollinate *B. purpurea*. The present study indicates that *B. variegata* with melittophilous pollination syndrome is pollinated by bees and passerine birds. Therefore, ornithophily gains importance in *B. variegata* in the context of simultaneously flowering plant species that attract bee species to different levels of flower constancy. With both melittophily and ornithophily, *B. variegata* is able to set fruit to 11% and this low fruit set seems to be compensated by a high seed set rate. The information provided on the association between *B. variegata* and bees and passerine birds is expected to be useful for their conservation in the habitat.

ACKNOWLEDGEMENTS

Financial support from the Ministry of Environment and Forests, Government of India, New Delhi through a Major Research Project (No. 30/12/97-RE) is gratefully acknowledged. We thank B. Madhu, Technical Assistant in the project for assistance in field and laboratory work. We thank the anonymous referees for helpful comments to revise the paper.

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21. *CERASTIUM FONTANUM* BAUMG. (CARYOPHYLLACEAE) – A NEW RECORD FOR RAJASTHAN[1]

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During a plant collection visit to Chattargarh, Bikaner district, Rajasthan, we collected *Cerastium fontanum* Baumg from marshy fields. A perusal of the literature shows that this genus has not been reported from Rajasthan.

The specimens of *Cerastium fontanum* Baumg are housed in the Herbarium, Department of Botany, Govt. Dungar College, Bikaner, Rajasthan.

The identification of the species is based on the FLORA OF INDIA (Sharma, B.D. and N.P. Bala Krishnan (1993), Vol. 2, B.S.I. Calcutta)

Cerastium fontanum Baumg Soc. Zool. Bot. Fenn. "Vanamo" 18:63. 1963. Flora of India 523, Vol 2 (1993).

Herbs, laxly caespitose, hirsute throughout or glandular-pubescent upwards. Leaves sessile, oblong, elliptic to ovate, acute at apex, 1-3 x 0.3-1.0 cm, minutely hairy. Cymes glandular-pubescent; bracts herbaceous. Sepals ovate-lanceolate, 3-5 mm long, with scarious margins and glabrous apex. Petals 2-fid for 1/3 to 1/5 of length, equalling or slightly exceeding sepals. Stamens 10; filaments glabrous; anthers yellow. Capsules narrowly cylindrical, 9-12 mm long; seeds 0.5-0.9 mm, reddish brown, rugose-tuberculate.

Fl. & Fr.: April-September.

Specimens Examined: Gowsala Chattargarh near Khala. Sharma & Kantiya. 1332

We are grateful to the Principal & Head Department of Botany, Dungar College, Bikaner. Thanks are also due to U.G.C. for providing financial assistance.

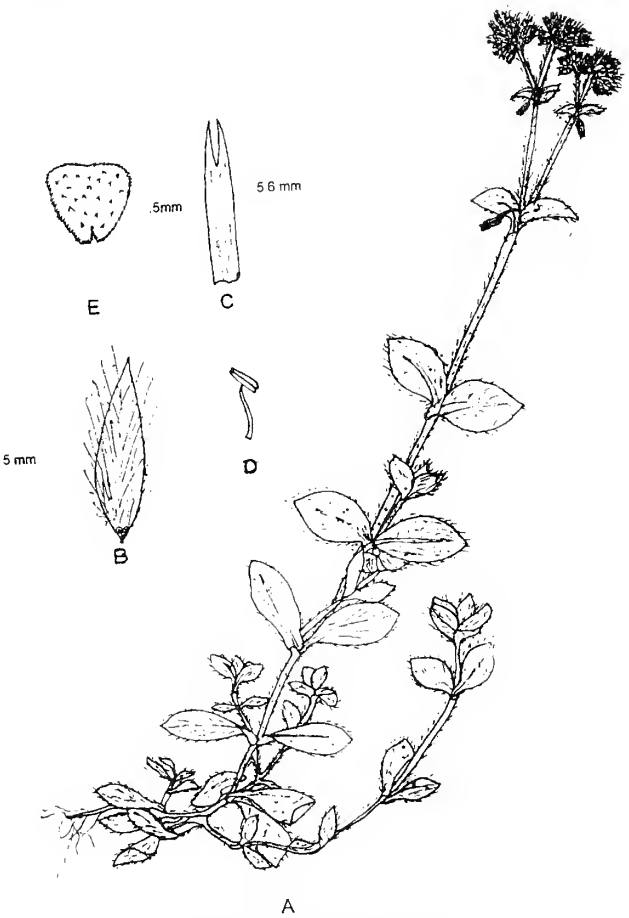

Fig. 1: *Cerastium fontanum* Baumg.
A. Plant; B. Sepal; C. Petal; D. Stamen; E. Seed

22. STUDIES ON THE GENUS *HERBERTUS* GRAY FROM MEGHALAYA, INDIA[1]

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Introduction

Herbertus Gray, a sole member of the Family Herbertaceae K. Muller from India is quite distinct in having hamato-secund 1/2-3/5 bilobed, long, narrowed, acuminate leaves; vitta cells elongate extending into the lobes (Schuster 1972, 1984). However, the genus *Herbertus* Gray was earlier treated under Family Ptilidiaceae Limpr., along with another genus *Trichocolea* Dumort. (Evans 1939). Earlier study on the genus *Herbertus* Gray in India was made by Mitten (1860-1861), Stephani (1909, 1922), Chopra (1938, 1943), Abeywickrama (1959), Miller (1965), Bonner (1966), Hattori (1966, 1971, 1975) and Herzog (1939), where most of the species were described from the eastern Himalayas. Udar and Srivastava (1977) described four species, namely *H. pinnata* (Steph.) Miller, *H. capense* (Steph.) Sim., *H. nilgerriensis* (Steph.) Miller and *H. sanguinea* (Mont.) Aust., from southern India. Parihar *et al.* (1994) listed 22 species, however, Kumar and Manocha (2000) while describing a new species *H. udarii* Kumar *et* Manocha from Darjeeling (eastern Himalayas) have mentioned only 23 species of *Herbertus* Gray in India. During the study on the liverworts of Meghalaya the presence of five taxa in Khasi Hills (Fig. 1) has been revealed. Amongst them *Herbertus fragilis*, *H. ceylanicus* and *H. sikkimensis* are being reported here from the Meghalaya for the first time. A considerable morphological plasticity among plant populations and species is discussed including remarks on distribution and ecology. A key to the species of the genus has also been provided.

The plant specimens were collected during April 1965, November 1998 and September 2000 from heavily moist localities, namely Elephant falls and Langkyrdum on Dawki road, Shillong (East Khasi Hills) Meghalaya. The specimens from various localities have been critically studied and compared with their paratype specimens obtained on loan from Field Museum Herbarium, USA. The collected specimens have been deposited in Bryophyte Herbarium, National Botanical Research Institute, Lucknow (LWG).

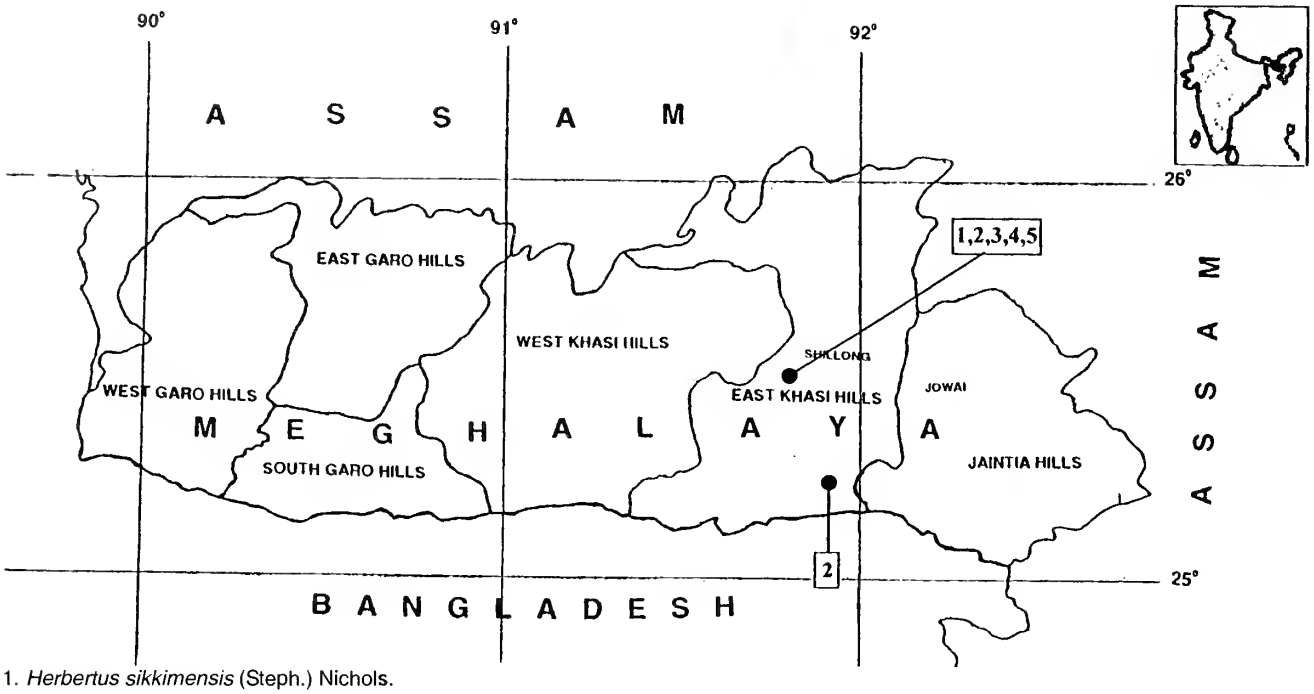
KEY TO THE SPECIES OF THE GENUS *HERBERTUS* GRAY IN MEGHALAYA

1. Leaves bifid ½ or less 2
— Leaves bifid 3/5 or more 3
2. Leaves larger, 1.75-1.88 mm long and 0.75-0.80 mm wide ..... *H. sikkimensis*
— Leaves smaller, 0.60-0.70 mm long and 0.15-0.18 mm wide 4
3. Leaves wider (0.83 mm wide), margin undulate with a lateral constriction at the junction of basal disc and lateral margin, vitta almost extending slightly above the leaf sinus furcation ..... *H. dicranus*
— Leaves less wider (0.53-0.70 mm wide), margin convex or rarely undulate without constriction, vitta almost extending to become the segment tip ..... *H. mastigophoroides*
4. Leaves sinus lunate, lobes more divergent, vitta almost to the base and extending to just below the tip..... *H. fragilis*
— Leaves sinus obtuse-subacute, lobes obtuse-subacute, vitta almost to the base and extending to just slightly above the leaf sinus furcation ..... *H. ceylanicus*

Herbertus sikkimensis (Steph.) Nichols., Miller, H.A., *J. Hattori Bot. Lab.* 28: 307 (1965); In Handel-Mazzetti *Symbolae Sinicae* 5: 28, 1930. (Figs 1, 2)

Plants medium-large, yellowish green or very light brownish green, 25-30 mm long and 2.50-2.75 mm wide including leaves. Stem 0.28 x 0.17 mm in diameter and 12-13 celled across; cortical cells in 2-3 layers, thick walled, smaller, 5.0 x 7.5 µm; medullary cells thin walled, smaller, 12.5 x 25.0-27.5 µm; frequently branched, branches with numerous attenuated flagelliform ventral intercalary branches. Leaves secund, bifid about 1/2 with acute-subacute, 1.15-1.25 mm deep sinus, nearly sinuately inserted, rigid, suberect-spreading, lobes lanceolate, acute-acuminate, margin entire, occasionally incurved, leaf lobes 1.75-1.88 mm long and 0.75-0.80 mm wide; leaf marginal cells 10.0-15.0 x 17.5 µm, smooth, rather thin walled, trigonous; median cells 12.5-15.0 x 17.5-20.0 µm, thin walled, with nodulose trigones; vitta cells elongated, thin walled, 17.5 x 37.5-57.5 µm, distinct large nodular trigones; vitta furcate, usually only for a short distance or 1/2 into the lobes. Underleaves greatly resembling the leaves; generally transversely inserted, 1.13-1.63 mm long and 0.68-0.70 mm wide, sinus subacute, 0.88-1.03 mm deep, suberect, lobes lanceolate, acute-acuminate, entire, with occasionally incurved margin.

Distribution and ecology: INDIA: North-eastern Himalaya: Meghalaya: East Khasi Hills: Elephant falls. Plants grow on bark in association with *Spruceanthus* sp., at 1,798 m altitude, 23.2 °C temperature and 74% relative humidity.



1. *Herbertus sikkimensis* (Steph.) Nichols.
2. *Herbertus dicranus* (Tayl.) Trev.
3. *Herbertus mastigophoroides* Miller
4. *Herbertus fragilis* (Steph.) Miller
5. *Herbertus ceylanicus* (Steph.) Miller

Fig. 1: Distribution of the genus *Herbertus* Gray in Meghalaya, India

Specimens Examined: INDIA: Meghalaya: East Khasi Hills: Elephant falls, 20.ix.2000, Leg. A.P. Singh, 208735-A (LWG). Det. V. Nath, A.K. Asthana & A.P. Singh.

Herbertus sikkimensis (Steph.) Nichols. was instituted by Stephani (1909), under the name *Schisma sikkimensis* Steph., from Sikkim Himalaya. Nicholson *et al.* (1930) and Miller (1965) in a monograph STUDIES ON *HERBERTA* in the Pacific and Asia described this species from Sikkim Himalaya. Moreover, Chopra (1943), Bonner (1966) and Parihar *et al.* (1994) listed *H. sikkimensis* (Steph.) Nichols. from the Eastern Himalaya. Hattori (1966) described *H. sikkimensis* as a synonym to *H. dicranus* (Inoue 1977; Long and Grolle 1990). Pippo (1990) listed it as a synonym of *H. dicranus* from China. However, during a recent study on Indian species of the genus *Herbertus* Gray, Manocha (1999) suggested the independent status of *H. sikkimensis* from *H. dicranus* on the basis of the comparative morphological and ultra microscopic studies of cuticle ornamentation over the leaf surface under SEM. This revealed that *H. sikkimensis* possesses the poorly developed transversely running lamellae over the laminar cells and verrucae arranged in a linear fashion over the vitta cells, while the laminar cells are verrucate but vitta cells show very fine lamellae running parallel to the cell length. The taxonomic account of the present species provided here is based on the study of specimens collected from the various localities of Meghalaya for the first time. The study revealed that *H. sikkimensis* approaches to *H. dicranus* (Tayl.) Trev. in possessing secund, spreading to somewhat recurved, decurrent, bifid leaves with acute sinus and slightly curved lanceolate segment with 1/2 twisted, acuminate tip. However, *H. sikkimensis* differs from *H. dicranus* in possessing wider plants, stem and less bifid smaller leaves, smooth vitta cells.

Herbertus dicranus (Tayl.) Trev., Inoue, H., *Bull. Nat. Sci. Mus., Ser. B (Bot.)* 3(1): 9, 1977; Miller, *J. Hattori Bot. Lab.* 28: 299-412, 1965. (Figs 1, 3)

Syn.: *Sendtnera dicrana* Tayl., in G.L.N., *Syn. Hep.* p. 239. 1845; *Herbertia dicrana* (Tayl.) Trevis., *Mem. R. Ist. Lombardo Sci.* 4: 397. 1877; *Schisma dicranum* (Tayl.) Steph., *Spec. Hep.* 4: 24 (1909).

Plants medium, brown-dark brown, 30 mm long and 1.88 mm wide including leaves. Stem 0.15-0.18 x 0.18 mm in diameter and 9-10 celled across; cortical cells in 2 layers, thick walled, smaller, 5.0 x 5.0-7.5 µm; medullary cells thin walled, larger, 17.5 x 20.0-22.5 µm; frequently branched with numerous attenuated, flagelliform, ventral intercalary branches. Leaves imbricate, secund, spreading to somewhat recurved, decurrent, bifid about 3/5 of the lobe with an acute sinus and slightly curved lanceolate segments with 1/2 twisted, acuminate tips, sinus 1.50 mm deep; leaf lobes 2.25 mm long and 0.83 mm wide; leaf marginal cells 10.0-12.5 x 15.0-17.5 µm, medium thick walled, trigonous; median cells

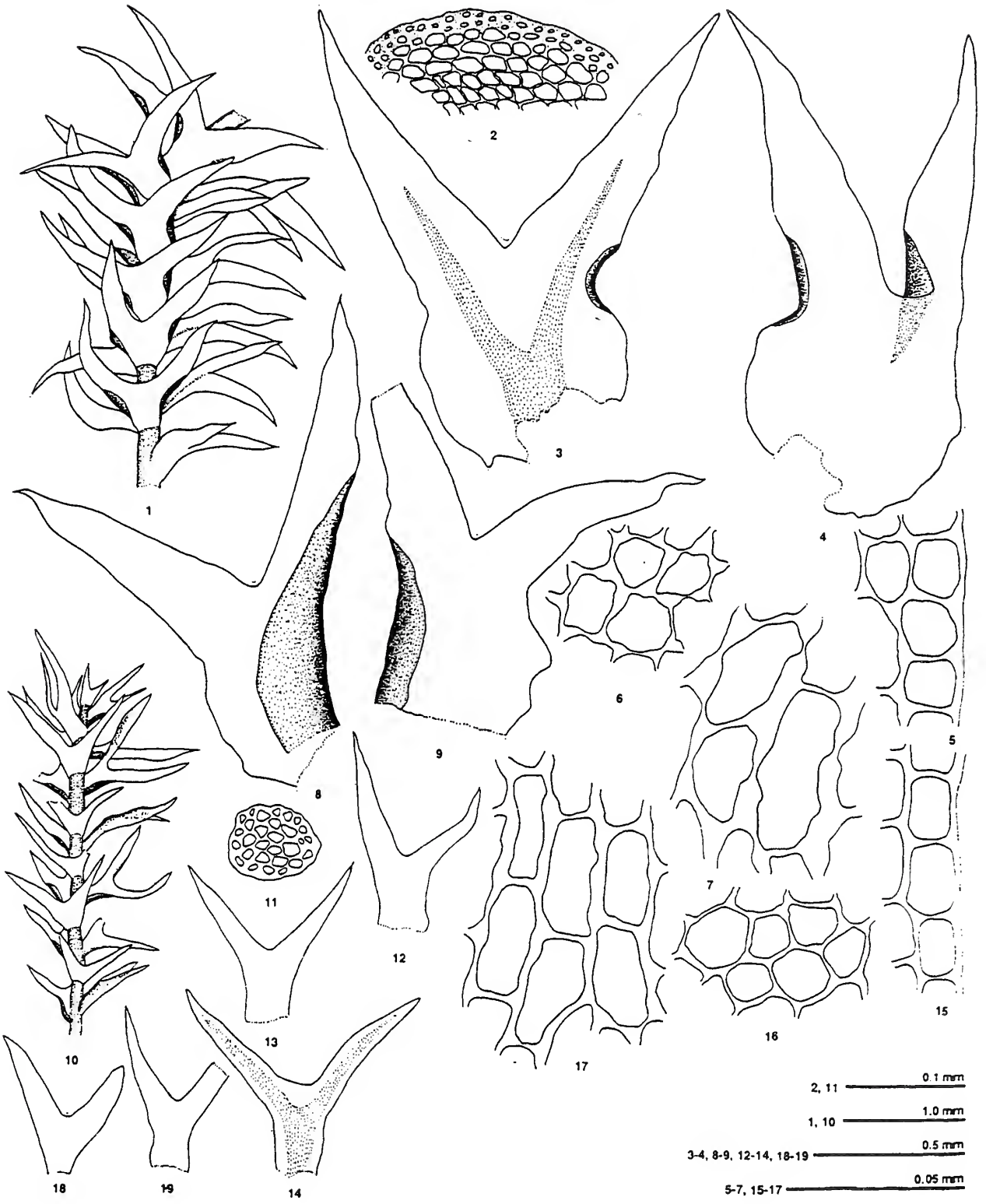


Fig. 2: *Herbertus sikkimensis* (Steph.) Miller. 1-9. (LWG 208735-A):
1. Plant ventral view; 2. Cross-section of stem; 3-4. Leaves; 5. Leaf marginal cells; 6. Leaf median cells;
7. Leaf basal cells; 8-9. Underleaves.
Herbertus fragilis (Steph.) Miller. 10-19. (LWG 208733-B):
10. Plant ventral view; 11. Cross-section of stem; 12-14. Leaves; 15. Leaf marginal cells;
16. Leaf median cells; 17. Leaf basal cells; 18-19. Underleaves

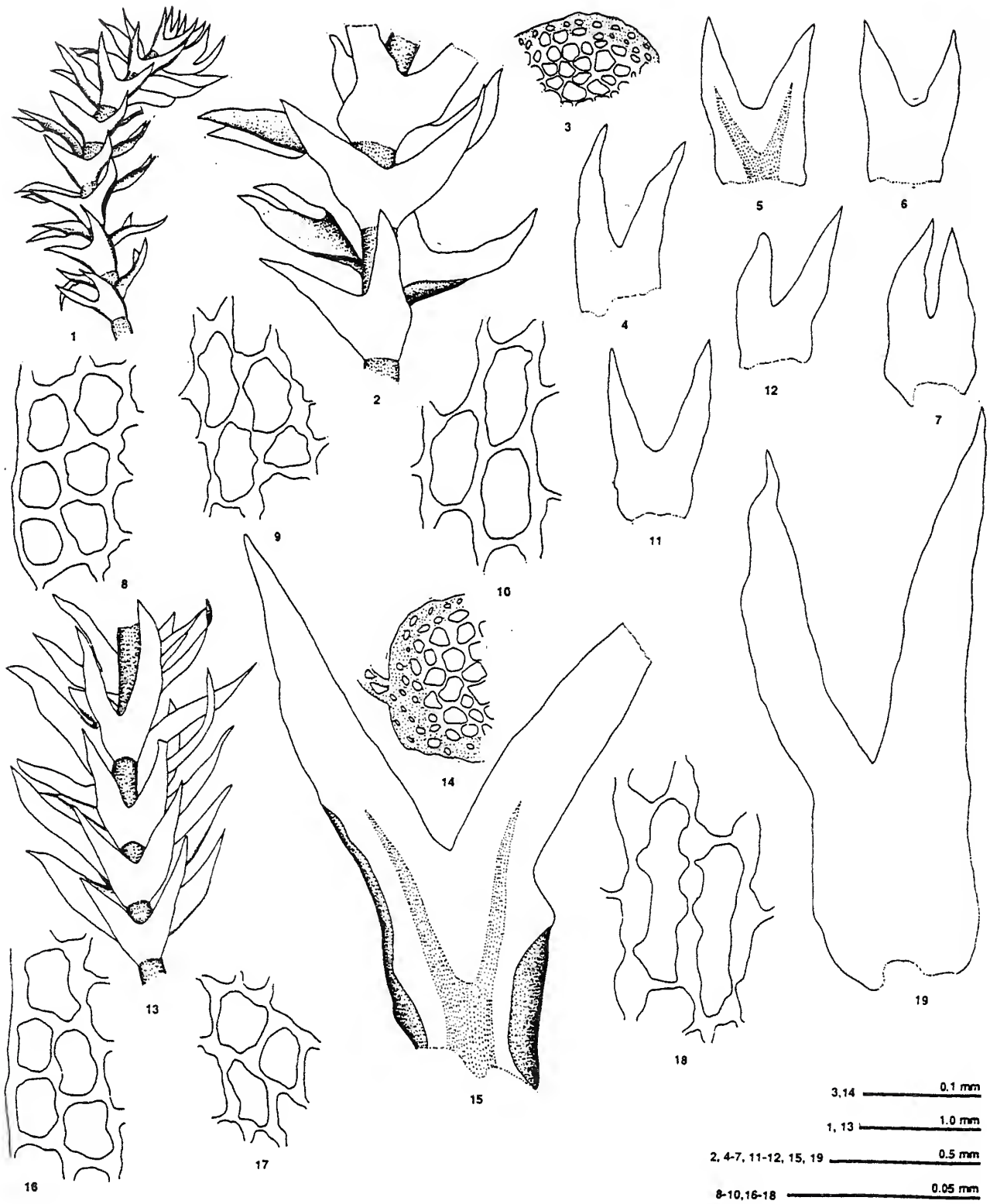


Fig. 3: *Herbertus ceylanicus* (Steph.) Miller. 1-12. (LWG 201208-A):
1. Plant ventral view; 2. Plant magnified view; 3. Cross-section of stem; 4-7. Leaves; 8. Leaf marginal cells; 9. Leaf median cells; 10. Leaf basal cells; 11-12. Underleaves
Herbertus dicranus (Tayl.) Miller. 13-19. (LWG 201215-B):
13. Plant ventral view; 14. Cross-section of stem; 15. Leaf; 16. Leaf marginal cells; 17. Leaf median cells; 18. Leaf basal cells; 19. Underleaf

Fig. 4: *Herbertus mastigophoroides* Miller. 1-10. (LWG 201214-D):
1. Plant ventral view; 2. Cross-section of stem; 3-5. Leaves;
6. Leaf marginal cells; 7. Leaf median cells; 8. Leaf basal cells; 9-10. Underleaves

12.5-15.0 x 22.5 µm, slightly thick to minutely thin walled, nodulose trigonous; basal cells or vitta cells very large, 15.0 x 55.0-62.5 µm, trigones nodulose; vitta narrow, concave-depressed, bifid below mid base and disappearing below the tip, leaf cells usually verrucose. Underleaves similar to leaves, generally transversely inserted and a little smaller, 2.00 mm long and 0.70 mm wide, sinus subacute, 1.28 mm deep, lobes lanceolate-acuminate, margin entire.

Distribution and ecology: INDIA: North-eastern Himalaya: Meghalaya: East Khasi Hills: Elephant falls, Langkyrdum Dawki Road, Nepal; China; Taiwan. Plants grow on plant bark and soil in association with *Marchantia polymorpha*, *Riccardia* sp., *Bazzania appendiculata*, *Plagiochila flexuosa*, *Cheilolejeunea serpentina*, *Lopholejeunea subfusca*, *Jungermannia* sp., and *Plagiochila* sp., at 1,385-1,402 m altitude.

Specimens Examined: INDIA: Meghalaya: East Khasi Hills: Elephant falls, 08.iv.1965, Leg. S. Chandra, 201215-B, 201216-A, 201222-D (LWG); Langkyrdum Dawki Road, 07.xi.1998, Leg. V. Nath, A.K. Asthana & A.P. Singh, 206058-E (LWG). Det. V. Nath, A.K. Asthana & A.P. Singh.

Other specimens examined: CHINA: Prov. Yunnan: Yulung Schan prope Urbem Lidjiang, 1915, Leg. Dr. H. Handel Mazzetti, 1136851(F), Cryptogamie exsiccatae editae a Museo Hist. Natur. Vindobonensi Cen. XXXVII Musci, Dec. 81-83, 1355858(F). Det. W.E. Nicholson; CHINA: Chiayico Mt. Alishan near the station, 09.iv.1978, Leg. M.J. Lai, 1029735(F), 10.iv.1978, Leg. M.J. Lai, 1029791(F). Det. M.J. Lai; CHINA: Drakensberg, Solitute resort Van Hayningens pass (foot) Mountain forest, July 1978, Leg. Arnold, 1088988(F); AFRICA COASTALE: Bujongalo (Valle mobuka), 1906, Leg. Tjediz, Deua & Dbrazzi, In the Cryptogamic Herbarium Chicago Natural History Museum, Det. Reurangeri; Taiwan: Between Jichu and Mt. Ari, Chia- Yi Hsien, 26.vii.1977, Leg. M. Michimori, 1029698(F). Det. H. Inoue.

Parihar *et al.* (1994) listed *H. dicranus* from eastern Himalayas and southern India. However, the present study is based on the plants collected from Elephant falls and Langkyrdum forest Dawki road, East Khasi Hills Meghalaya for the first time. This taxon shows similarities with *H. sikkimensis* but distinctly differs in certain features as already mentioned in the discussion part of *H. sikkimensis.* A comparative study of the Meghalaya *H. dicranus* with paratypes showed remarkable variation in morphological features. It has been considered as the adaptation of the plant against diverse environmental habitat.

Herbertus mastigophoroides Miller, *J. Hattori Bot. Lab.* 28: 299-412 (1965). (Figs 1, 4)

Plants long, brown-greenish brown, 50 mm long and 1.55 mm wide including leaves. Stem 0.20 x 0.23 mm in diameter and 11 celled across; cortical cells in 2 layers, much thick walled, smaller, 2.5-5.0 x 5.0 µm; medullary cells thin walled or very slightly thick, larger, 17.5 x 22.5-25.0 µm; frequently branched with numerous ventral intercalary branches. Leaves imbricate to approximate, obliquely inserted, falcate-secund when dry and erect-secund when moist, decurrent, bifid 2/3-3/4 with an acute sinus, lobes lanceolate with acuminate tips, sinus 1.20-1.25 mm deep; leaf lobes 1.75-2.05 mm long and 0.53-0.70 mm wide; leaf marginal cells 12.5-17.5 x 20.0-22.5 µm, thin walled, with nodulose trigones; median cells 10.0-12.5 x 30.0 µm, thin walled, trigones nodulose; vitta cells narrow, slightly grooved, yellowish, bifid nearly to the base, and extending to become the segment tip; leaf cells poorly verrucose. Underleaves similar to leaves but transversely inserted, 1.63 mm long and 0.45-0.53 mm wide, sinus somewhat more rounded, 1.13-1.40 mm deep, lobes divergent, margin entire.

Distribution and ecology: INDIA: North-eastern Himalaya: Meghalaya: East Khasi Hills: Elephant falls. Plants grow on plant bark in association with *Lepidozia* sp., *Bazzania appendiculata*, *Odontoschisma denudatum*, and *Jungermannia* sp., at 1,371 m altitude.

Specimens Examined: INDIA: Meghalaya: East Khasi Hills: Elephant falls, 08.iv.1965, Leg. S. Chandra, 201214-D, 201218-A (LWG). Det. V. Nath, A.K. Asthana & A.P. Singh.

Herbertus mastigophoroides Miller was instituted for the first time by Miller (1965) from Darjeeling, Sikkim Himalaya. Parihar *et al.* (1994) listed *H. mastigophoroides* from eastern Himalaya. The present study is based on the plants collected from Elephant falls, East Khasi Hills, Meghalaya. This species shows resemblance with *H. dicranus* (Tayl.) Miller and *H. sikkimensis* (Steph.) Nichols. in colour, length of the plant, leaf length, nodular trigones and vitta cells. *H. mastigophoroides* differs from *H. dicranus* in possessing stem 11 celled across, 0.20 x 0.23 mm in diameter, leaves 2/3-3/4 bifid, 1.75-2.05 mm long and 0.53-0.70 mm wide, vitta bifid, nearly to the base and extending to become the segment tip. On the other hand *H. sikkimensis* differs from *H. mastigophoroides* in possessing much wider plants (2.50-2.75 mm wide), stem 12-13 celled across, leaves 1/2 bifid, 1.75-1.88 mm long and 0.75-0.80 mm wide; vitta furcate, usually only for a short distance or 1/2 into the lobes having smooth vitta cells.

Herbertus fragilis (Steph.) Miller, *J. Hattori Bot. Lab.* 28: 299-412, 1965; Del. Rosario, R.M., Philipp. *J. Sci.* 104(1-2): 28 (1975). (Figs 1, 2)

Syn.: *Schisma fragile* Steph., *Spec. Hep.* 6: 359, 1922.

Plants small, greenish brown-dull brown, 15-20 mm long and

1.88-2.00 mm wide including leaves. Stem 0.07 x 0.08 mm in diameter and 6 cells across; cortical as well as medullary cells slightly distinct; cortical cells smaller, one layered, thick walled, 5.0-7.5 x 7.5-12.5 µm; medullary cells thin walled, larger, 10.0-12.5 x 15.0 µm; irregularly branched, with both normal and microphyllous branches. Leaves oblong, almost transversely inserted, approximate-imbricate, erect-subspreading, bifid 1/2-2/3 with an open acute sinus and narrowly lanceolate, segments, sinus 0.40-0.46 mm deep, leaf lobes 0.16-0.18 mm wide and 0.60-0.70 mm long; leaf marginal cells 10.0-12.5 x 17.5-22.5 µm, rather thin walled, indistinct to minutely trigonous; median cells 12.5-15.0 x 20.0-22.5 µm, thin walled, trigonous; basal cells or vitta cells 12.5 x 35.0-37.5 µm, distinct, with large nodular trigones; vitta narrow, shallow, grooved, bifid almost to the base and extending to just below the tip; leaf cells poorly verrucose. Underleaves similar to leaves, generally transversely inserted, 0.56-0.60 mm long and 0.15 mm wide, sinus subacute-obtuse, 0.39 mm deep, lobes divergent, lanceolate-acuminate, with entire margin.

Distribution and ecology: INDIA: North-eastern Himalaya: Meghalaya: East Khasi Hills: Elephant falls. Plants grow on rocks in association with *Cephalozia* sp., and *Cephaloziella* sp., at 1,798 m altitude, 23.20 °C temperature and 74% relative humidity.

Specimens Examined: INDIA: Meghalaya: East Khasi Hills: Elephant falls, 20.ix.2000, Leg. A.P. Singh, 208733-B (LWG). Det. V. Nath, A.K. Asthana & A.P. Singh.

Herbertus fragilis (Steph.) Miller was instituted for the first time by Stephani (1922) under the name *Schisma fragile* Steph. from Sikkim Himalaya. Miller (1965) described this species from Sikkim Himalaya. Parihar *et al.* (1994) also listed this species from eastern Himalaya. However, the present study is based on the plants collected from the Elephant falls, East Khasi Hills, Meghalaya for the first time. *Herbertus fragilis* shows resemblance with *H. ceylanicus* (Steph.) Miller, in plant's length, colour, leaf sinus and length, however, latter differs from former in possessing 1.25 mm wide plants including leaves, stem 9 cells across, 0.13 x 0.16 mm in diameter, leaf lobes subobtuse-subacute, not divergent, vitta bifid, nearly to the base and extending to a little bit of sinus, vitta cells smooth.

Herbertus ceylanicus (Steph.) Miller, *J. Hattori Bot. Lab.* 28: 299-412, 1965; Onraedt, M., *J. Hattori Bot. Lab.* 50:191-216 (1981). (Figs 1, 3)

Syn.: *Schisma ceylanicum* Steph., *Spec. Hepat.* 4: 22. 1909.

Plants small to medium, yellowish brown to brown, 15 mm long and 1.25 mm wide including leaves. Stem 0.13 x 0.16 mm in diameter and 9 cells across; cortical cells in 1-2 layers, smaller, thick walled, 5.0-7.5 x 7.5 µm; medullary cells larger, thin walled, 15.0 x 25.0-32.5 µm; frequently branched, branches bearing reduced but otherwise normal leaves for a considerable distance before becoming microphyllous and flagelliform. Leaves imbricate- approximate, subjulaceous when dry and erect spreading when wet, oblong, clasping at the base but not decurrent, 0.60-0.66 mm long and 0.30-0.34 mm wide, bifid about 1/2 with a broadly acute sinus and broad straight acute segments; sinus 0.35-0.45 mm deep; leaf marginal cells 12.5 x 12.5-17.5 µm, thick walled, trigonous; median cells 12.5 x 12.5-20.0 µm, thin walled, trigones nodulose; basal or vitta cells 7.5-10.0 x 32.5 µm, thin walled, with nodular trigones; the vitta cells bifid nearly to the base and extending to a little bit of sinus; leaf cells usually smooth. Underleaves similar to the leaves, 0.60-0.70 mm long and 0.28-0.30 mm wide, sinus acute-subacute, 0.42-0.43 mm deep, lobes less divergent, margin entire.

Distribution and ecology: INDIA: North-eastern Himalaya: Meghalaya: East Khasi Hills: Elephant falls; Sri Lanka. Plants grow on plant bark in association with *Chandonanthus birmensis, Cheilolejeunea* sp., *Plagiochila* sp., at 1,385 m altitude.

Specimens Examined: INDIA: Meghalaya: East Khasi Hills: Elephant falls, 08.iv.1965, Leg. S. Chandra, 201205-A, 201208-A (LWG). Det. V. Nath, A.K. Asthana & A.P. Singh.

Herbertus ceylanicus (Steph.) Miller was instituted by Stephani (1909) from Ceylon under the name *Schisma ceylanica* Steph. Miller (1965) described *H. ceylanicus* (Steph.) Miller from Ceylon and stated that there is a specimen of *Schisma ceylanicum* Steph. in Herbarium G (India orientalis in Mte Moolegit, Leg. Fea, 1887, Portion du type). Hattori (1966) described this species from Ceylon and India. Parihar *et al.* (1994) also listed this species from eastern Himalaya. However, the present study is based on the plants collected from Elephant falls in East Khasi Hills, Meghalaya for the first time. The study revealed that the *H. ceylanicus* approaches to *H. fragilis* (Steph.) Miller, but latter differs in having leaves with lunate sinus, lobes more divergent, vitta cells almost to the base and extending to just below the tip.

ACKNOWLEDGEMENTS

We are grateful to The Curator, Field Museum of Natural History, Illinois USA for lending the Paratype specimens; the Director, National Botanical Research Institute, Lucknow for his encouragement and providing the facilities. We thank the Department of Science and Technology, New Delhi for

providing the financial assistance and the Council of Scientific & Industrial Research, New Delhi for awarding Senior Research Fellowship and Research Associateship to one of the authors (APS). Thanks are also due to the Chief Conservator of Forests, Meghalaya for his kind help during exploration of various localities of the Khasi, Jaintia and Garo hills.

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Printed by Bro. Leo at St. Francis Industrial Training Institute, Borivli, Mumbai 400 103 and published on January 09, 2009 by J.C. Daniel for Bombay Natural History Society, Hornbill House, Dr. Sálim Ali Chowk, Shaheed Bhagat Singh Road, Mumbai 400 001, Maharashtra, India.

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Printed by Bro. Leo at St. Francis Industrial Training Institute, Borivli, Mumbai 400 103 and published by J.C. Daniel for Bombay Natural History Society, Hornbill House, Dr. Sálim Ali Chowk, Shaheed Bhagat Singh Road, Mumbai 400 001.
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